Experiment - 7

Humidification & Dehumidification setup

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Objective :-

To study the mass transfer operation in humidification and dehumidification column for different flow & thermodynamic conditions.

Aim :-

1) To calculate the humidity for humidification & dehumidification process
2) To calculate the mass transfer co-efficient in the humidification column.

Theory :-

The mass transfer co-efficient ka, can be measured in a humidification & dehumidification column in which the area of contact between two phases is known and boundary layer separation does not take place. A humidification & dehumidification column also provide useful information on mass transfer to and from fluids in turbulent flow.

For turbulent flow mass transfer to pipe wall involving evaporation of liquids in wetted wall towers, Gilliland and Sherwood proposed the correlation :-

Various dimensionless groups that control the phenomenon are :-

$$N_{Sh} = 0.023 \times N_{Re}^{0.81} \times N_{Sh}^{0.44}$$

$$\frac{ka \times d}{D} = 0.023 \left(\frac{d \times V \times \rho}{\mu}\right)^{0.81} \left(\frac{\mu}{d \times \rho}\right)^{0.44}$$

$$ka = \frac{0.023 \times D}{d} \left(\frac{d \times V \times \rho}{\mu}\right)^{0.81} \left(\frac{\mu}{d \times \rho}\right)^{0.44}$$

where,

Reynald's number, $N_{Re} = dV\rho/\mu$

Schmidt Number, $N_{Sc} = \frac{\mu}{\rho D}$

Sherwood Number, $N_{Sh} = kad/D$

The known flow rate of air at a measured humidity is brought into contact with a film of water at a certain temperature and vapour pressure. Moisture is absorbed by the air from water film and the resultant humidity of the exit air and the temperature measured.

Experimental Procedure :-

1) Ensure the switches given on the panel are at OFF position.
2) Close all the values provided on the set up.
3) Fill the sump tank with water.
4) Connect the air supply to the set up.
5) Connect electric supply to the set up.
6) Set the desired air temperature in the DTC by operating the increment or decrement and set button of DTC.
7) Fill wet bulb bottle with water
8) Switch ON the pump.

9) Allow water to flow through condenser by control valve provided

10) Start the compressed air supply & adjust the flow rate of air by rotameter provided

11) Start the operation with minimum air flow.

12) Switch on the heater and wait till desired temperature achieves.

13) Allow water to flow through humidification column and adjust the flow rate by rotameter and control valve.

14) After every 10-15 mins, note down the temperature and flow rate readings of air by DTI & rotameter provided up to steady state

15) Note temp. of water & flow rate

16) Repeat for different air & water flow rates

Observations :-

group D

S.No	Fa	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Fw
1	15	26.5	26.3	32.1	30.2	26.4	26.2	26.6	26.3	26.5	27.0	30
2	23	26.6	26.7	37.1	33.2	26.6	26.8	27.3	26.5	27.1	26.7	30
3	23	26.7	26.5	37.3	33.5	26.8	26.7	27.3	26.6	27	26.3	45
4	23	26.3	26.4	37.4	34.3	27.1	26.5	27.5	27.1	27.3	27.1	60

Calculations :- For set 1 readings

To calculate the Humidity of air H_1, H_2, H_3, H_4 at temperature (T_3 & T_4), (T_5 & T_6), (T_7 & T_8) and (T_9 & T_{10})

from psychometric chart

$H_1 = 0.0267$ kg of H_2O / kg of air

$H_2 = 0.0215$ kg of H_2O / kg of air

$H_3 = 0.0216$ kg of H_2O / kg of air

$H_4 = 0.0218$ kg of H_2O / kg of air

T = mean temp of inlet and outlet air

$$T = \frac{T_3 + T_5}{2} = \frac{32.1 + 26.4}{2}$$

$\Rightarrow 29.25°C$

The property of air (μ, ρ) at temperature $(T°C)$ from data book:—

$\Rightarrow \mu = 1.857 \times 10^{-5}$ Ns/m²

$\rho = 1.152022$ kg/m³

A = cross sectional area of column

$$\Rightarrow \frac{\pi}{4} d^2$$

$$\Rightarrow A = \frac{\pi}{4} (0.048)^2$$

$\Rightarrow 1.809 \times 10^{-3}$ m²

$$V = \text{velocity of air} = \frac{Fa}{1000 \times 60 \times A}$$

$$\Rightarrow \frac{15}{1000 \times 60 \times 1.809 \times 10^{-3}}$$

$\Rightarrow 0.13819$ m/s

Ka = gas film co-efficient

$\Rightarrow$

$$k_a = \frac{0.023 \times D}{d}\left(\frac{d \times v \times \rho}{\mu}\right)^{0.81}\left(\frac{\mu}{d \times \rho}\right)^{0.44} \text{ (m/s)}$$

$$\Rightarrow \frac{0.023 \times 25.83 \times 10^{-6}}{0.048}\left(\frac{0.048 \times 0.13819 \times 1.152022}{1.857 \times 10^{-5}}\right)^{0.81}$$

$$\left(\frac{1.857 \times 10^{-5}}{0.048 \times 1.152022}\right)^{0.44}$$

$k_a = 4.8054 \times 10^{-5}$ m/s

Calculation Table :—

S No.	H_1	H_2	H_3	H_4	k_a
1	0.0267	0.0215	0.0216	0.0218	4.8054×10^{-5}
2	0.0312	0.0221	0.0217	0.0221	6.7549×10^{-5}
3	0.0318	0.0222	0.0218	0.0221	6.7519×10^{-5}
4	0.0337	0.0218	0.0227	0.0227	6.7508×10^{-5}

Results :—

we determined the humidity for humidification & dehumidification process from the Experiment along with the mass transfer co-efficient ka in the humidification column. H_1, H_2, H_3, H_4 and ka, were calculated using psycometric charts and data book.

we noticed that mass transfer co-efficient increases as we increase the rate of air but does not change much if keep the flow of air constant and increase that of water

Sources of Error:-

1) The temperature might not be stable and reading may have been taken wrong leading to error.

2) There may have been error while measuring the flow rates of water and air in rotameter due to parallax error as well as due to flow rate being altered by the faulty Equipment.

3) wet bulb baffle must be filled with enough water or it may result in faulty readings.

Conclusion:-

1) we noticed that by increasing the air flow rate the rate of mass transfer increases due to which we will get better mass transfer (Humidification / Dehumidification)

2) This is in accordance with theory as flow rate of air increases its velocity causing increase in Ra which will increase ka

3) The trend for change in the flow rate of water, keeping flow rate of air constant could rather found as ka almost remained constant. which is in accordance with the theory.

Precautions :-

1) Never run the apparatus if Power supply is less than 200 volts and more than 230 volts

2) Never switch ON mains power supply before ensuring that all the ON/OFF switches given on the panel are at OFF position.

3) operator selector switch of temperature indicator gently.

4) Always keep the apparatus free from dust.

5) Wet bulb bottle should be filled with water before starting the Experiment.

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