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Experimental Analysis of Mixed Flow Liquid Desiccant Dehumidification System

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ABSTRACT

The current environment makes people very dependent on traditional air conditioning systems. But the problem with conventional air conditioning systems is to create suffocation when we use extra time due to the high moisture in the air. Here we implement a device. It reduces the relative humidity in the atmosphere, A liquid desiccant dehumidifier has been created with this in mind. One desiccant dehumidifier unit, air handling equipment, and desiccant handling equipment. The primary objectives of the present study are to determine the impact of inflow parameters on system performance and the ideal parametric conditions for moisture condensation rate. Many experimental studies were conducted to support this. The object of the work demonstrates that the moisture condensation rate rises with rising flow rate, desiccant concentration, and desiccant flow rate.

Keywords - $CaCl_2$, Liquid Desiccant, Relative humidity

1. INTRODUCTION

A liquid desiccant Dehumidification cooling system is a type of air conditioning system that uses liquid desiccants (such as lithium chloride or calcium chloride solutions) to absorb moisture from the air before it is cooled. This system can be more energy efficient than traditional air conditioning systems because the desiccant solution can be regenerated using solar energy rather than electricity.

We need to reduce the humidity in the atmospheric air with the help of Desiccant (Cacl2) mixed with water in different concentrations and flow rates. If humidity is high in the atmosphere it leads to suffocation in humans and fungal formation on food products, so We reduce the relative humidity in the atmosphere with our experimental setup.

The dehumidifier is the most crucial part of this liquid desiccant dehumidification system. where mass transfer between the two fluids occurs when a liquid desiccant comes into direct contact with moist air. The moister air is dehumidified in the dehumidifier, and the desiccant is diluted because moisture is transported from the air to the desiccant. The solution has become weak at that point. Desiccant that has been diluted may be utilized repeatedly with fresh 5% desiccant mixed to create rich solutions, but I am constructing a prototype here. Although the regenerator is used to reuse the diluted weak solution; I did not utilize a regenerator. With the assistance of air handling equipment, which has two fans to produce a draught to control the air.

This dehumidified air is transferred through an air conditioning system it produces cool dry air, gives comfort to humans without any suffocation, it dry and preserves food products like, (Meet, Bred. etc), it prevents fungal formation.

Here I am looking for many articles based on liquid desiccation dehumidification to Identify air behavior, when we modify input parameters like (Flow & Desiccation Concentration). [1] In this article, we focus mainly on mass transfer performance data with crossflow structure and dehumidifier efficiency. The high efficiency comes with the cross-flow structure filling system. [2] In this article, my focus is on the design parameters and experimental configuration for obtaining a change in relative humidity in atmospheric air. [3] In this paper, I explore which input parameters work best in the de-humidification process. So, I choose the changing input parameters with this paper and perform experiments based on this research.

2. METHODLAGY

Structural packing (100*80*80 mm3) offering a contact area of 40m2 was used for direct contact with the structural packing absorber unit. This structural packing is made up of iron mesh covered with a cotton cloth for better condensation between them, For dehumidification, the return air is brought in contact with the liquid desiccant running down the Structural packing of the absorber unit in cross flow to the air stream and the water spray nozzles with a spray angle of 900 are placed above the structural packing unit at a distance of 3cm, to distribute the liquid desiccant uniformly over the Structural packing, allowing a different solution flow rate. The contact Structural packing absorber unit is designed for a maximum Desiccant flow rate the inlet and outlet temperatures of the return air and the salt solution. Additionally, Digital humidity sensors were used to measure the relative humidity of the return air at the inlet and outlet of the Structural packing absorber unit. Also, measure the Inlet and Outlet air velocities with help of a pyranometer. Measuring temperatures with the help of a Digital thermometer.

Fig 1: Dehumidification system

2.1 DESICCANT SOLUTION:

The Common liquid desiccant for dehumidification in air conditioning and industrial drying applications is calcium chloride ($CaCl_2$). By absorbing moisture from the air, liquid desiccant function, and calcium chloride has a particularly strong affinity for water vapor.

The liquid desiccant is often run through a heat exchanger in a calcium chloride-based liquid desiccant dehumidification system, where it picks up moisture from the air that passes over the exchanger's surface.

The desiccant that has absorbed moisture is subsequently heated to drive it off, usually using a different heat source.

1. High moisture absorption capacity: Calcium chloride is a very efficient evaporator of moisture from the air because of its capacity to absorb up to twice as much moisture as its weight.

Table 1: Properties of Calcium Chloride

2.2 DEHUMIDIFIER

CaCl2	Calcium Chloride
Molecular Weight	110.98g/mol
Density	Anhydrous: 2.15kg/m^3
Boiling Point	1935^0C
Melting Point	772^0C

The dehumidifier unit in a liquid desiccant dehumidification system oversees utilizing the liquid desiccant to eliminate moisture from the air. A heat exchanger, a liquid desiccant pump, and a regeneration heat source regularly make up a dehumidifier unit.

The part that makes touch with the air to be dried off is the heat exchanger. For the liquid desiccant to absorb moisture as effectively as possible, it is often built to maximize the surface area exposed to the air. The liquid desiccant pump oversees moving the desiccant through the heat exchanger so that it can draw moisture from the atmosphere.

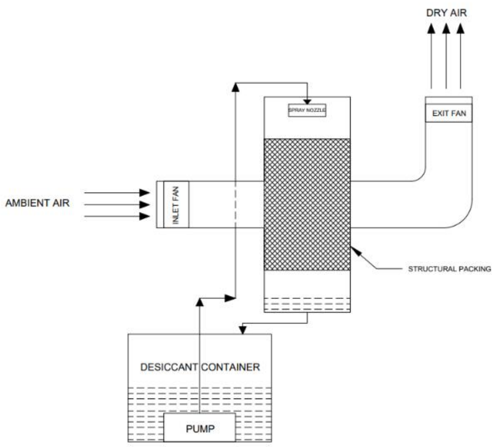


Fig 2: Dehumidifier unit

2.3 AIR HANDLING:

In our experimental setup air handling equipment is necessary for the suction of air from the atmosphere and delivery to the room. For that we place two fans, one is an inlet of the dehumidifier and the second one is placed at the outlet of the dehumidifier with that we archive the required flow rate of atmospheric air to the dehumidified air. With this process, we completely enclose the dehumidifier because it disturbs the air path so completely close all sides of the dehumidifier.

These two fans are creating a draught in a dehumidifier, with these fans we set a path for the atmospheric air, so that we get better dehumidification when compared to the normal conditions, so artificial draught is getting good results.

These two fans are connected to DC Motors on each side, these two motors are connected by a mobile charging adaptor, this adaptor changes the ac power supply to the dc power supply, with that dc power DC Motors start running then the Suction and Delivery fans are start rotating and creating a draught.

2.4 DESICCANT HANDLING:

In this experimental setup, Desiccant (Cacl2) is mixed with water initially in a Below Storage tank it is made up of plastic. This highly concentrated mixture is transferred from the tank to a dehumidifier with help of an 18W Submerged pump, which lifts the desiccant to a 2M head. We place the Dehumidifier within the 2M range. So, we got a maximum flow rate of the Submerged pump.

In this process, we set a bypass for regulating the Desiccant mixture flow rates. For regulation purposes, we place a valve mechanism, which helps to regulate the desiccant flow rates. So, we conduct this experiment with the different flow rates

At the End of the pipe, we set up a sprayer it has 12 small holes it sprays the desiccant along the dehumidifier unit. This desiccant mixture is condensed with the air, absorbs the moister from the air, and then diluted this diluted solution is again mixed with the additional 5% of Desiccant then it becomes a rich solution. Then this process is a continuous process.

The power supply to this Submerged pump is AC 220-240V, 50Hz power frequency, so we directly plugin to our sockets to get an AC supply it transfers to the Submerged Pump which lifts the Desiccant Mixture.

3. INDENTATIONS AND EQUATIONS

3.1 NOMENCLATURE:

m	mass flow rate, kg s-1
Ɛ	dehumidification effectiveness
ω	humidity ratio, kg kg-1 DA
a	surface area density, m2 m-3
h	enthalpy, kJ kg-1
P	vapor pressure, kPa
q	heat transfer rate, kW
T	temperature, 0C
X	concentration, kg kg-1
Z	height of packing, m Subscripts
Cond	condensed moisture
equ	equilibrium state
s	Desiccant solution
w	water
1	inlet
2	outlets
a	air

Psychrometric Chart Indentations

T_{dbt}	Dry Bulb Temperature ^{0}C
T_{wbt}	Wet Bulb Temperature ^{0}C
T_{dew}	Dew Point Temperature ^{0}C
x	Absolute Humidity kg/kg DA
RH	Relative Humidity
ρ	Air Density kg/m3
P_v	Vapor Pressure Pa

3.2 ENERGY BALANCE EQUATION:

The structural packing is taken as a control volume, here mass transfer interaction between the liquid desiccant sprayed at the top of the dehumidifier and the humid air entering from the inlet to the control volume.

The energy balance can be expressed as follows, assuming that there is very little heat loss or gain to the CV. As well as it gives the mass flow rates at the inlet and outlet.

$$\mathbf{m_{s1}h_{s1} + m_a h_{a1} = mah_{a2} + m_{s2}h_{s2}} \qquad \textbf{(1)}$$

The outlet liquid desiccant solution flow rate, ms2, can be written as

$$\mathbf{m_{s2} = m_{s1} + m_{cond}} \qquad \textbf{(2)}$$

3.3 AIR:

Inlet Diameter (d1) = 65mm
Outlet Diameter (d2) = 65mm
Inlet velocity (v1) = 1.5m/s
Outlet velocity (v2) = 1.5m/s

Air Density (ρ) = 1.16kg/m^3

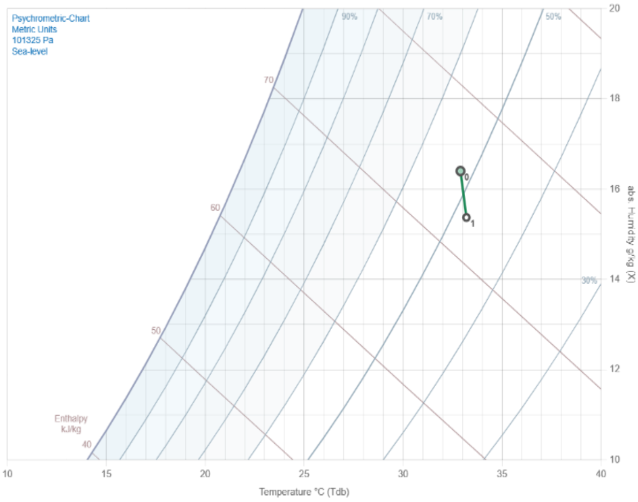


Fig 3: Air Psychrometric chart

Point	Tdb [°C]	Twb [°C]	Tdew [°C]	X [g/kg]	H [kJ/kg]	RH [%]	ρ [kg/m³]	Pv [Pa]
0	32.9	24.7	21.7	16.4	75.1	52	1.142	2603
1	33.2	24.1	20.7	15.4	72.8	48	1.142	2444

Table 2: Air Dehumidification Data

3.4 DESICCANT:

Concentration (X) = 0.75kg/kg
Inlet Desiccant Temperature = 33.1°C
Outlet Desiccant Temperature = 33.5°C

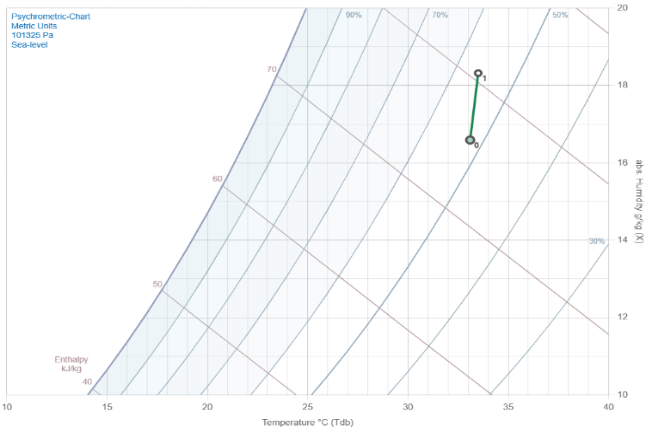


Fig 4: Desiccant Psychrometric Chart

Point	Tdb [°C]	Twb [°C]	Tdew [°C]	X [g/kg]	H [kJ/kg]	RH [%]	ρ [kg/m³]	Pv [Pa]
0	33.1	24.9	21.9	16.6	75.8	52	1.141	2633
1	33.5	26	23.5	18.3	80.6	56	1.139	2899

Table 3: Desiccant Humidification Data

3.5 CALCULATIONS:

Therefore, Eq. (1) can be rewritten as

$$\mathbf{m_a(h_{a1}+h_{a2}) = ms1(h_{s2}-h_{s1}) + m_{cond}h_{s2}} \quad (3)$$

Where:

$m_{cond} = m_a (\omega_1 - \omega_2)$ $m_a = \rho * a * v1$

$m_a = 1.16 * (\pi d2)/4 * 1.5$ ma= $1.16 * (\pi (0.065)2)/4*1.5$

$\mathbf{m_a = 5.7738 * 10\text{-}3\ kg/sec}$

Data is taken from Table2 & Table3

Where: -

ω_1= 0.0164 Kg/Kg of Da

ω_2= 0.0154 Kg/Kg of Da ha1=75.1 KJ/Kg of Da

h_{a2}=72.8 KJ/Kg of Da

h_{s1} =75.8 KJ/Kg of Da

h_{s2}=80.6 KJ/Kg of Da

m_{cond}=5.7738*10-3 (0.0164-0.0154)

$$\mathbf{m_{cond} = 5.7738*10\text{-}6kg/sec} \quad (4)$$

5.7738 *10-3(75.1 – 72.8) =m_{s1}(80.6-75.8) +m_{cond}* h_{s2}

All the above parameters are substituted in eq (3)

5.7738 *10-3(75.1 – 72.8) =m_{s1}(80.6-75.8) +5.7738*10-3(0.0164-0.0154)

m_{s1}= [5.7738 *10-3(75.1 – 72.8)- 5.7738*10-3(0.0164-0.0154)]/ (80.6-75.8)

$$\mathbf{m_{s1} = 0.0026695\ Kg/sec} \quad (5)$$

Substitute eq (4) & eq (5) in eq (2) to get the mass flow rate at the outlet of the desiccant.

ms2=0.0026695 +5.7738*10-3(0.0164- 0.0154)

ms2=0.0026695+5.7738*10-6

ms2=0.0026752738 Kg/sec

4. RESULTS:

We test our experimental setup in different conditions for how our system works, and how much it is feasible when compared to the theoretical and research work. Here we test the equipment in Different periods with different desiccant concentrations.

As well as we test this experimental test rig with different desiccant mixture flowrates in different desiccant concentrations. With varying flow rates and desiccant concentrations, how the system performs and how much dehumidification is possible is identified.

These are the Results for the Different periods with Different Desiccant concentrations

- Flow Rate: -0.1125kg/sec
- Air inlet Velocity: -1.5m/sec
- Air Outlet Velocity: -1.5m/sec

S.no	Date	Time	Desiccant (%)	Water (%)	Inlet		outlet		Difference in RH (%)
					Tdbt (^{0}C)	RH (%)	Tdbt (^{0}C)	RH (%)	
1	15/03/2023	10 AM-11 AM	5	95	30.1	63	31.2	62	1
		4 PM-5 PM			29.6	67	30.4	66	1
		8 PM-9 PM			28.4	72	29.2	71	1
2	16/03/2023	9 AM-10 AM	10	90	31.2	56	30.5	55	1
		12 PM-1 PM			31.9	65	0.4	63	2
		7 PM-8 PM			28.8	64	28.5	62	2
3	19/03/2023	7 AM-8 AM	15	85	26.6	70	27.9	68	2
		11 AM-12 PM			30.6	65	32.4	63	2
		6 PM-7 PM			28.7	69	29.4	67	2
4	21/03/2023	6 AM-7 AM	20	80	32.2	71	33.9	69	2
		3 PM-4 PM			31.2	68	34.2	65	3
		11 PM-12 AM			30.6	55	29.8	52	3
5	22/03/2023	5 AM-6 AM	25	75	26.2	75	27.5	71	4
		2 PM-3 PM			32.9	56	31.4	53	3
		1 AM-2 AM			27.4	68	28.9	65	3

Table 4: Dehumidification in Different Periods

These are the Results for Different Flow rates of desiccant and Different concentration mixtures.

- Air Inlet Velocity: -1.5m/sec
- Air Outlet Velocity: - 1.5m/sec
- Varying Flow rates & Varying Concentrations in the same period

S.no	Desiccant Flow Rate (kg/min)	Desiccant (%)	Water (%)	Inlet		Outlet		Difference in RH (%)	Percentage Change
				Tdbt (^{0}C)	RH (%)	Tdbt (^{0}C)	RH (%)		
1	3.75	5	95	32.1	66	33.6	66	0	0
		10	90	31.5	53	32.2	52	1	0.019
		15	85	26.7	65	26.3	64	1	0.015
		20	80	30.6	59	31.2	57	2	0.029
		25	75	31.1	62	30.4	60	2	0.033
2	4.35	5	95	32.6	66	32.6	65	1	0.015
		10	90	31.4	52	32.6	51	1	0.019
		15	85	26.8	64	28.5	62	2	0.032
		20	80	28.7	57	29.4	55	2	0.036
		25	75	34.2	60	33.5	58	2	0.034
3	4.95	5	95	32.5	65	33.7	64	1	0.015
		10	90	32.1	51	31.5	49	2	0.040
		15	85	27.2	62	28.3	60	2	0.033
		20	80	29.5	55	30.2	52	3	0.057
		25	75	34.5	58	33.4	55	3	0.054
4	5.55	5	95	31.2	64	30.5	63	1	0.015
		10	90	31.4	49	32.2	47	2	0.042
		15	85	27.5	60	28.6	57	3	0.052
		20	80	28.6	52	29.4	49	3	0.061
		25	75	33.8	55	32.4	52	3	0.057
5	6.15	5	95	32.1	63	31.6	62	1	0016
		10	90	31.6	47	32.4	45	2	0.044
		15	85	28.7	57	29.4	55	2	0.036
		20	80	29.2	49	30.6	46	3	0.065
		25	75	32.9	52	33.2	48	4	0.083
6	6.75	5	95	32.7	62	33.6	61	1	0.016
		10	90	31.8	45	32.8	43	2	0.046
		15	85	27.6	55	28.4	52	3	0.057
		20	80	29.2	46	30.5	43	3	0.069
		25	75	33.5	48	32.6	44	4	0.090

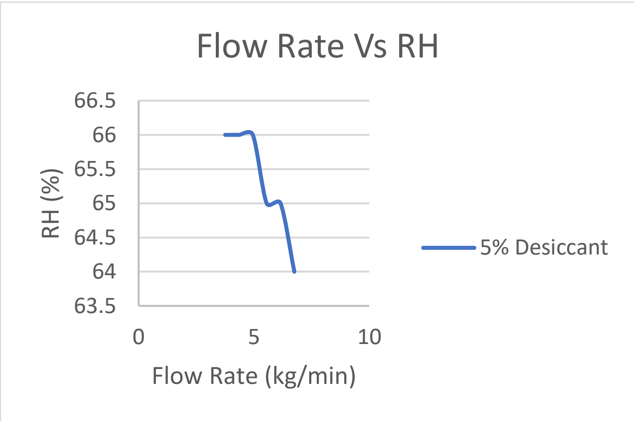
Table 5: Dehumidification data With Different Flow Rates and Different concentrations

Here we take the Experimental Results for Different Flow rates with a constant Desiccant Concentration mixture. We found better results in this combination.

S. No	Desiccant in %	Desiccant Flow Rate (kg/min)	Inlet RH (%)	Outlet RH (%)
1	5	3.75	66	66
2		4.35	66	65
3		4.95	65	64
4		5.55	64	63
5		6.15	63	62
6		6.75	62	61

Table 6: At 5% Desiccant

At 5% Desiccant is mixed with water and Conducted experiments at Different flow Rates For a long timeWe get a Relative Humidity Change of 2% only.



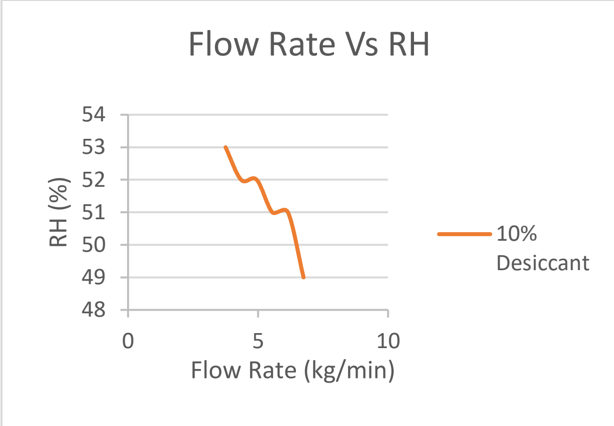
Graph 1: At 5% Desiccant

Similarly For 10% also

S. No	Desiccant in %	Desiccant Flow Rate (kg/min)	Inlet RH (%)	Outlet RH (%)
1	10	3.75	53	52
2		4.35	52	51
3		4.95	51	49
4		5.55	49	47
5		6.15	47	45
6		6.75	45	43

Table 7: At 10% Desiccant

At 10% Desiccant is mixed with water and Conducted experiments at Different flow Rates For a long time We get a Relative Humidity Change of 5% only.



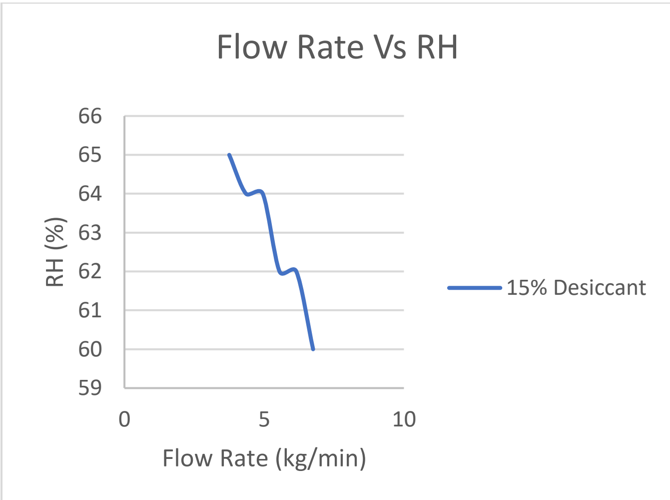
Graph 2: At 10% Desiccant

Similarly For 15% also

S. No	Desiccantin %	Desiccant Flow Rate (kg/min)	Inlet RH (%)	Outlet RH (%)
1	15	3.75	65	64
2		4.35	64	62
3		4.95	62	60
4		5.55	60	57
5		6.15	57	55
6		6.75	55	52

Table 8: At 15% Desiccant

At 15% Desiccant is mixed with water andConducted experiments at Different flow Rates For a long time We get a Relative Humidity Change of 5% only.



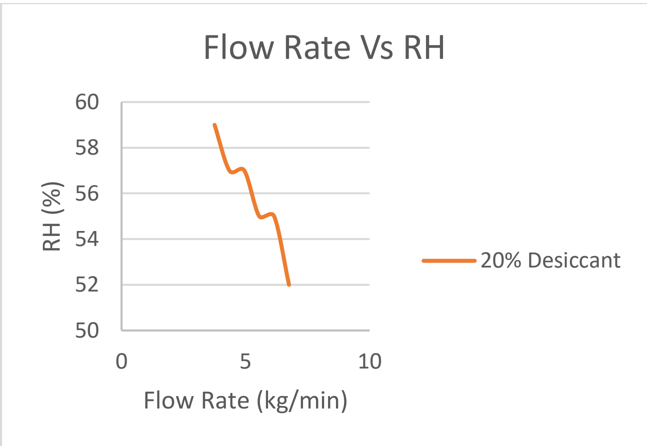
Graph 3: At 15% Desiccant

Similarly For 20% also

S. No	Desiccant in %	Desiccant Flow Rate (kg/min)	Inlet RH (%)	Outlet RH (%)
1	20	3.75	59	57
2		4.35	57	55
3		4.95	55	52
4		5.55	52	49
5		6.15	49	46
6		6.75	46	43

Table 9: At 20% Desiccant

At 20% Desiccant is mixed with water and Conducted experiments at Different flow Rates For a long time We get a Relative Humidity Change of 7% only.



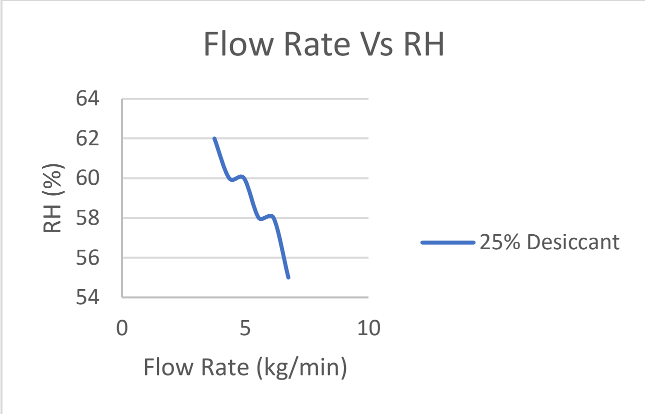
Graph 4: At 20% Desiccant

Similarly For 25% also

S. No	Desiccant in %	Desiccant Flow Rate (kg/min)	Inlet RH (%)	Outlet RH (%)
1	25	3.75	62	60
2		4.35	60	58
3		4.95	58	55
4		5.55	55	52
5		6.15	52	48
6		6.75	48	44

Table 10: At 25% Desiccant

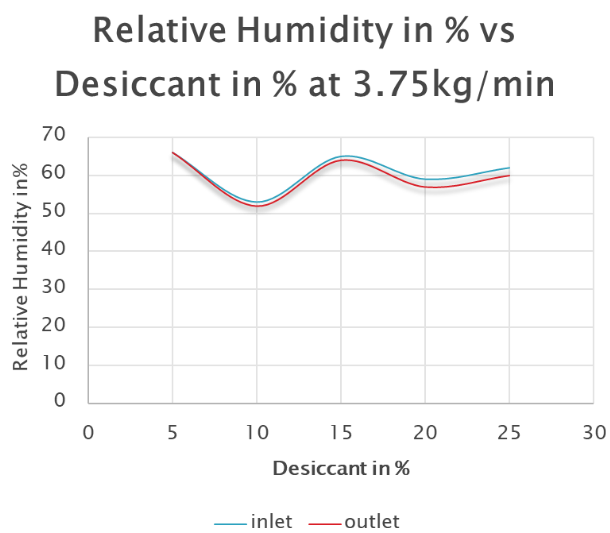
At 25% Desiccant is mixed with water andConducted experiments at Different flow Rates For a long time We get a Relative Humidity Change of 7% only.



Graph 5: At 25% Desiccant

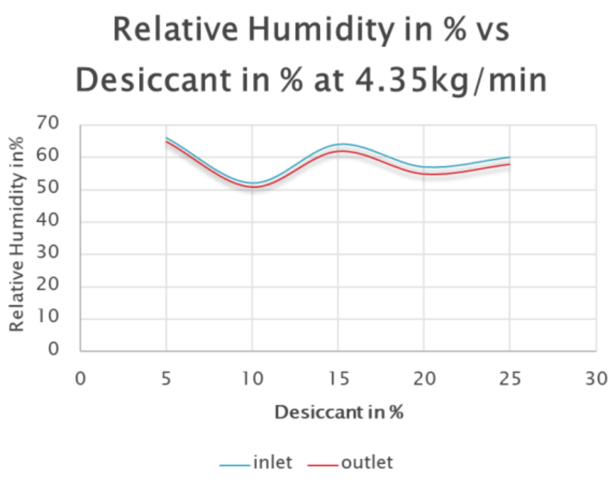
For Better Understanding, we plot Different graphs for Different flow rates And different Desiccant concentrations mixtures and how relative humidity changes.

From this graph, we observe that relative humidity slightly reduces a little bit. If we increase the flow rate there is a chance of decreasing relative humidity in the atmosphere.



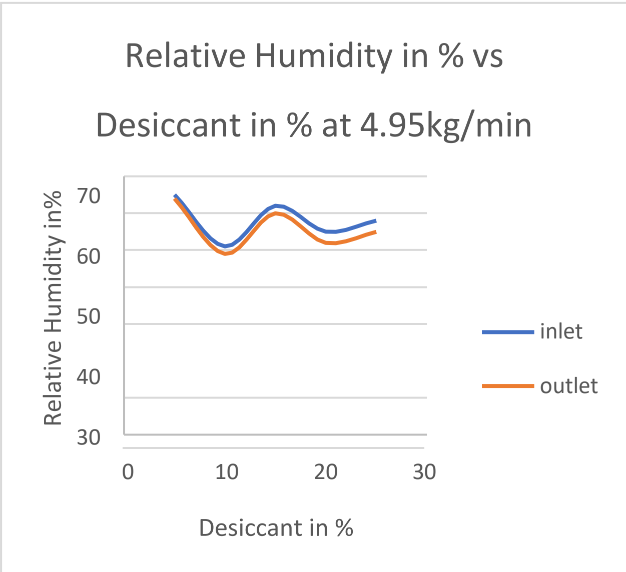
Graph 6: Desiccant vs RH At 3.75kg/min

If you observe these different flow rates and concentration graphs, inlet Relative humidity is high compared to outlet relative humidity. At maximum concentration difference is high.



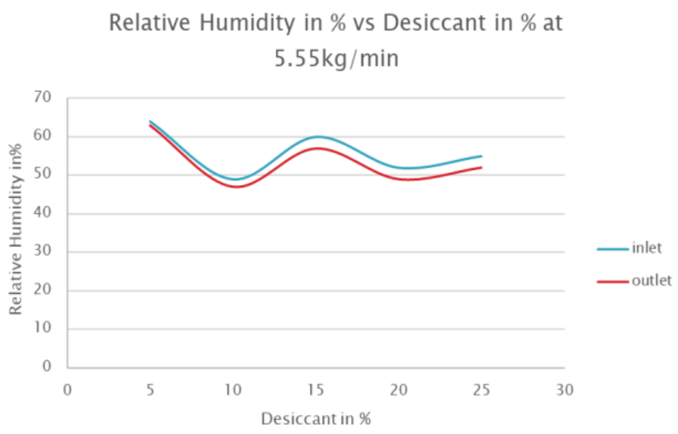
Graph 7: Desiccant vs RH At 4.35kg/min

Similarly, all these graphs show the maximum difference when we mix more desiccant concentration with a constant Flow rate.



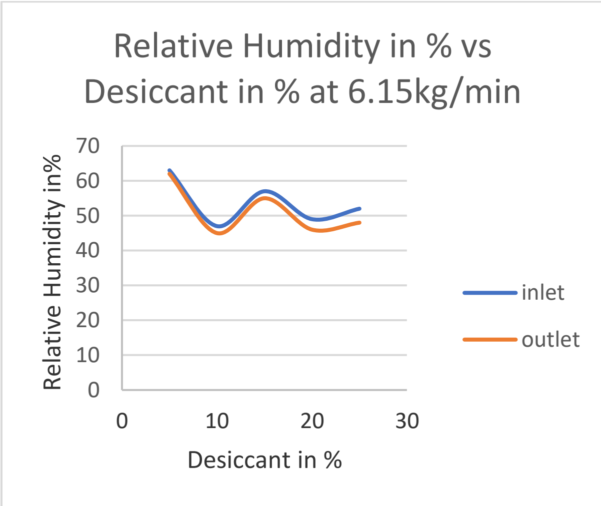
Graph 7: Desiccant vs RH At 4.95kg/min

The inlet relative humidity to the outlet humidity is very slight variations we observe with constant flowrates. So, we need to increase the flow rate so we get a better condensation effect with these concentrations.

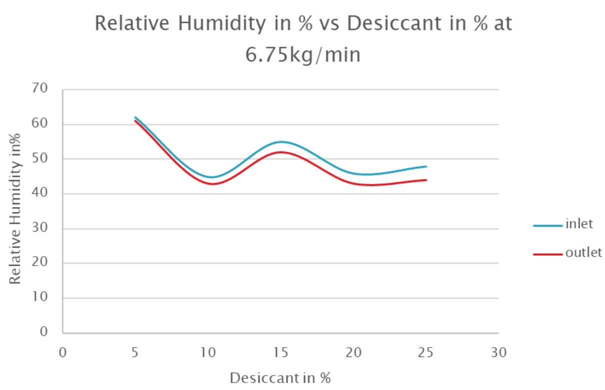


Graph 9: Desiccant vs RH At 5.55kg/min

Similarly at 6.15 And 6.75 Flow rates also wegot variations in the relative humidity levels.



Graph 10: Desiccant vs RH At 6.15 kg/min



Graph 11: Desiccant Vs RH At 6.75kg/min

5. CONCLUSION:

Experimental studies are carried out on liquid desiccant dehumidifier unit, in order to optimize various operating parameters, based on the Experimental analysis. From the experimental studies, the following conclusions have been made.

Effective condensation is possible with a high mass flow rate of the desiccant Mixture, as well as the concentration percentage is also crucial for better condensation created in the dehumidifier unit.

Here, our system is testing under the different flow rates and concentration percentages, We note down what we getting from our system, with these results plot some graphs, and then observe those graphs. Finally, we conclude that with the high mass flow rate of the desiccant mixture and the high concentration percentage of desiccant, we got a better relative humidity change.

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