

# Experimental Investigation of the Padding Tower<sup>1</sup>

## for Air Dehumidifier

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**Abstract:** Air conditioning with all fresh air is founded on the principle of dehumidifying by liquid desiccant. It has the characteristics of being clean, power-saving, easy to operate, and requiring low-grade heat. It is suitable for applying waste heat, and solar power as the heat source for regeneration. Hence, this system has a great latent potential for energy savings and environmental protection. The system chooses the padding tower as a dehumidifier and regenerator, which are often used in petrochemical industry. The system chooses a padding tower as a dehumidifier, and LiCl-Water as a liquid desiccant. The vapor in the air is absorbed by the spray of the LiCl solution, and then the absorbed vapor will be released by heating the absorbent. These processes form the circle of absorptive refrigeration operating in atmospheric pressure.

This paper describes studies on the theory and experiment of the padding tower of the dehumidifying air conditioning, including selecting different padding and measuring the speed of the air flow and the solution flow and the pressure drop between the layers of the padding. The experimental and computational results indicate that the design parameters of the padding tower significantly influence the characteristics of the liquid desiccant air conditioning. Of these design parameters, the framework of the padding tower, ratio of the air and the concentration of the inlet solution is largest through the tower, the temperature and effects of the dehumidifying capability of the tower.

**Key words:** liquid desiccant, air conditioning with all fresh

## 1. INTRODUCTION

The air conditioning system with all fresh air possesses the characteristics of cleaning, power-saving,

easy operating and low grade heat of requiring etc. the system may make use of industry waste heat. solar power and reproducible energy, so it has bigger potential of energy-saving and environment protecting. The system selects padding tower to deal with the supply air of air conditioning system, in the tower the vapor in the air is absorbed by LiCl brine solution to make the air dry. At the same time the thin desiccant solution will be desorbed in the regenerator. In this way an absorption refrigeration circle worked at atmospheric pressure is obtained. The system can get low temperature supply air to meet the need of air conditioning.

The dehumidifying process in the padding tower, dehumidifier, is a complex heat and mass transfer process. The impetus of the mass transfer is the vapor pressure difference between handled air and the surface of the desiccant solution. When the vapor pressure of the handled air is higher than the surface vapor pressure of the desiccant solution, the vapor will transfer from gas phase to liquid phase. When the contact time between gas and liquid phases is fully long, the mass transfer process will arrive to poise. In the process the vapor of the air is absorbed to make the air dry and the desiccant solution absorbs the vapor to be diluted. The diluted solution after heated is sent into regenerator, there the vapor pressure of brine solution is higher than the vapor pressure of ambient air imported for regenerating, the vapor transfer from liquid phase to gas phase to realize the desiccant solution regenerate. The regenerated dense solution will be sent back to the dehumidifier to carry out the dehumidification process. Therefore a continuous circle process is formed.

## 2. PADDING TOWER DEHUMIDIFIER

2.1 dehumidifier device description

The dehumidifier in the experiment system is adiabatic. The desiccant through it is LiCl brine solution. The rule padding in the tower is 350Y ripple metal board and material is 316L stainless steel. The flow mode of the air and solution is countercurrent. In order to ensure the dehumidifying performance of the adiabatic dehumidifier, the device equips a outside circle water cooler to make the solution before entering the dehumidifier be cooled.

2.2 The work condition selection of the dehumidifier

The main parameters of the dehumidifier are the ratio of air and solution and the air pressure drop through the device. Based On the mass balance, the reduced vapor quantity of the air should equal to the vapor quantity absorbed by solution. The mass transfer quantity in absorption process shows below.

$$dG = VdY = LdX \text{ kmol} / s \tag{2-1}$$

$V$ --the air quantity through the parked type tower in unit time,  $m^3/s$ ;

$L$ --the desiccant solution quantity through the parked type tower in unit time,  $m^3/s$ ;

$dX, dY$ --the vapor content difference of the air and

solution in the high of  $dZ$ ,  $kmol/m^3$ .

In the stable and continuous work process, we can have that formula, namely relation operation linearity Equation.

$$V(Y_1 - Y_2) = L(X_1 - X_2) \tag{2-2}$$

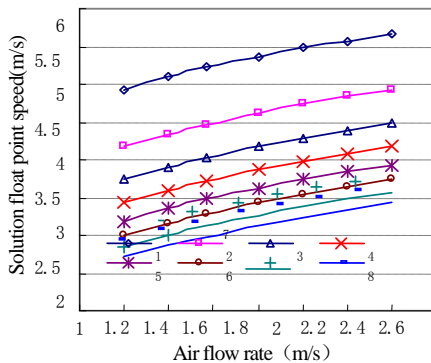
$X_2, Y_1$ --the vapor content of solution and air at the bottom of the tower,  $kmol/m^3$ ;

$X_1, Y_2$ --the vapor content of solution and air at the top of the tower,  $kmol/m^3$ .

The operation linearity Equation reflects the vapor content variety relation in any section of the tower. On the above equation, the right design parameters of the system are searched.

2.2.1 Confirming the range of air flow quantity, solution flux and pressure drop in the tower

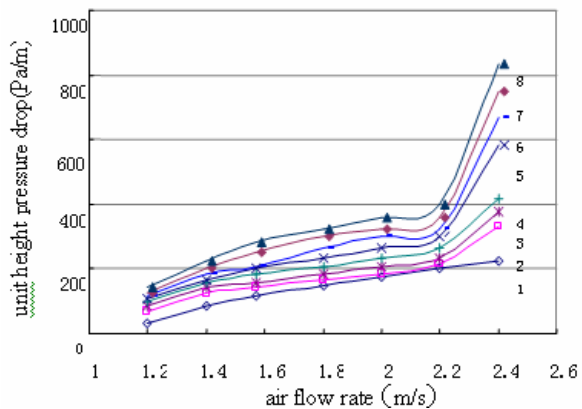
On the least ratio of air and solution, 1.2~2.4m/s the air flow rate range and 0.2m/s variety rhythm are selected. The range of solution flux and the variety rhythm of solution flux respectively choose  $4.8 \times (1 \sim 8) m^3/m^2/h$  and  $4.8 m^3/m^2/h$ . The solution float point speed is calculated by the Bain-Haugen formula. The upper limit of solution flux is related with the wetness rate of padding. When the wetness rate of padding approaching 100%, the flow quantity is the upper limit of solution flux. The calculation result shows at Fig.1 The number of 1~8 represent the variety of solution flux in the range of  $4.8 \times (1 \sim 8) m^3/m^2/h$ . The air flow rate is limited by the solution float point speed. From the Fig.1, it is known that the float point speed is related nearly with solution flux. Along with the increase of solution flux, the solution float



(a)  
(b)

**Fig.1 The variety of solution float point speed and unit height pressure drop with air flow rate under  $4.8 \times (1 \sim 8) m^3/m^2/h$  solution flux**

point speed become gradually small. Usually the air flow rate is less than 75% of the solution float point speed. As the Fig.1(a) shows, when the air flow rate arrives at 2.4m/s, the solution flux shouldn't exceed  $4.8 \times 8 m^3/m^2/h$ ,



when the air flow rate is below 1.8m/s, all of the solution flux ranges satisfy the limit of the float point speed of the solution.

Fig. 1(b) reflects unit padding height pressure drop

along with the air flow rate variety under different solution flux. At the 2.2m/s air flow rate, every curve presents an inflexion. It is indicated when the air flow rate is larger than 2.2m/s the unit padding height pressure drop will arise markedly. Otherwise, when the air flow rate keeps constant, along with solution flux increase the unit padding height pressure drop also adds. Moreover the larger the air flow rate is, the more quickly bigger the value of unit padding height pressure drop also adds. So the air flow rate may as well be less than 2.2m/s.

2.2.2 Confirming the padding height

The padding height influences both the contact persistence time of air and solution and the balance degrees between air and solution in the dehumidifying process. Owing to the pressure drop in the tower presenting linear variety along with height of padding, so it is necessary to confirm the proper padding height.

According to the aforementioned variety rule of pressure drop and liquid float, when the air flow rate of

empty tower is set between 1.2~2.2 m/s, the solution flux can vary in the range of  $4.8 \times (1\sim8)$  m<sup>3</sup>/m<sup>2</sup>/h. Now we set that the selected empty tower air flow rate is 1.6m/s, the total padding height is 0.4~1.6 m.

Fig. 2(a) reflects the pressure drop variety in the tower along with the padding filling height variety under different solution flux. Under same solution flux, the total pressure drop of the tower adds lineally along with the increase of padding height. Fig. 2 (b) reflects the air vapor content variety at the tower outlet along with the padding filling height variety under different solution flux. Under same solution spray density, the dehumidification quantity decreases along with the increase of padding height. Arrived at one padding height the air vapor content variety tends to slowness along with padding height increase, namely arriving at the optimal padding height of air dehumidification. The table 1 lists several groups of preferable data relating padding height.

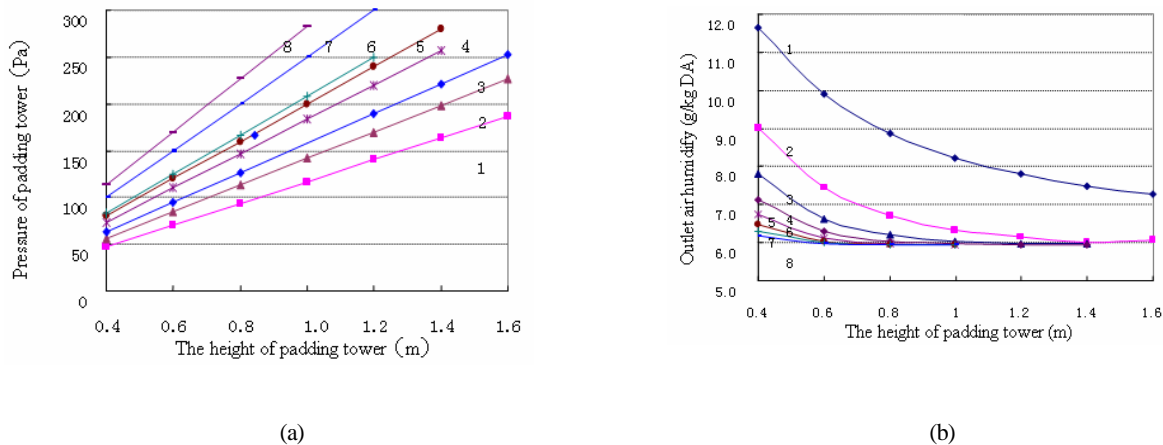


Fig.2 The variety of total pressure drop of the padding tower and outlet air humidity with padding height under difference solution flux

Tab. 1 Several groups of ideal data relating with padding height

Solution flux (m <sup>3</sup> /m <sup>2</sup> /h)	Total padding height in the tower (m)	Total pressure drop of the tower (Pa)	Air vapor content at outlet of the tower (g/kg)
2×4.8	1	141.7	8.3
3×4.8	0.8	126.7	8.9
4×4.8	0.6	110.0	9.2

Thus the inlet parameters of dehumidification tower are selected. a. The range of the air flow rate is 1.0~3.0m/s, the air flow rate increases 0.4m/s in every experiment operation. b. The range of the solution flux

variety is  $4.8 \times (1\sim8)$  m<sup>3</sup>/m<sup>2</sup>/h, the value of the solution flux increases 4.8m<sup>3</sup>/m<sup>2</sup>/h in every experiment operation. c. The range of the air inlet temperature is 28~40°C, the air inlet temperature increases 2°C in every experiment

operation. d. The range of the air inlet absolute humidity is 12~24g/kg, the air inlet absolute humidity increases 2g/kg in every experiment operation. e. The range of the solution temperature is 25~40°C, the solution temperature increases about 1°C in every experiment operation. In experiment process each parameter among the parameter of a~e is adjusted from the minimum to the maximum, other parameter keep constant. After the system running steadily, the data of the dehumidifier operating are collected and tracked recorded. A team of curves concerned in inlet parameter of dehumidifier effecting dehumidification efficiency are obtained after analysing and clearing up the data.

### 3. EXPERIMENT RESULTS ANALYSIS

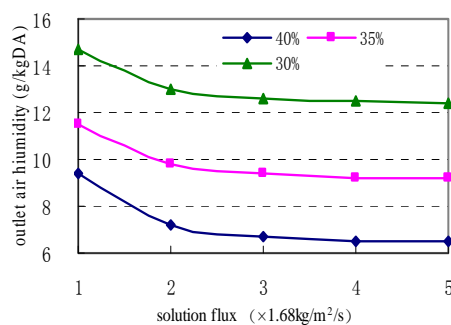
In the research of experiment, the test element of the air temperature, relative and absolute humidity, and solution temperature are adopted by T type thermocouple. The test device of the air flow rate adopts Y type pitot tube and micromanometer. LZB-40 type glass rotameter is used to measure solution's flowing speed. All parameter

values are real time data collected by ADAM-4018+ collection module and ADAM-4520 type diversion module, and transferred to computer through RS-232 serial port.

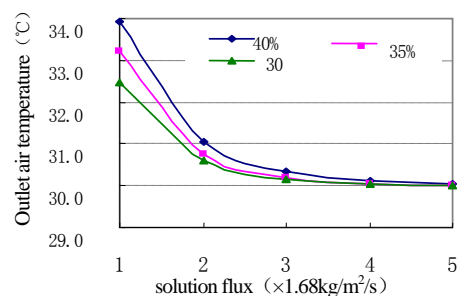
#### 3.1 The affection of inlet solution flux to outlet air humidity and temperature

Fig.3 and Fig.4 respectively describe the affection of every inlet parameter to the outlet parameter of air and solution or to the change of dehumidification capacity. These figures reflect the variety direction of effecting outlet parameters and dehumidifying efficiency along with the change of inlet parameters of solution and air with difference solution concentration.

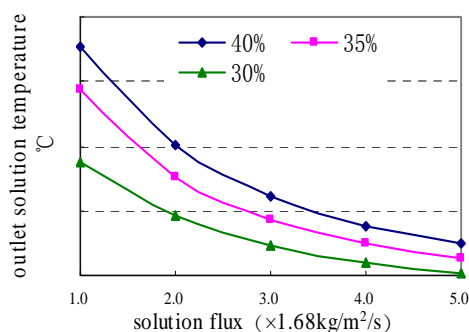
Fig.3(a), (b), (c) reflect that the outlet humidity and temperature of air and solution outlet temperature will fall if solution flux increases. The increasing of solution flux makes heat and mass transfer more sufficient, but to unit solution flux, the sensible heat and potential heat absorbed by liquid desiccant also decrease, so solution outlet temperature shows a falling current when inlet solution.



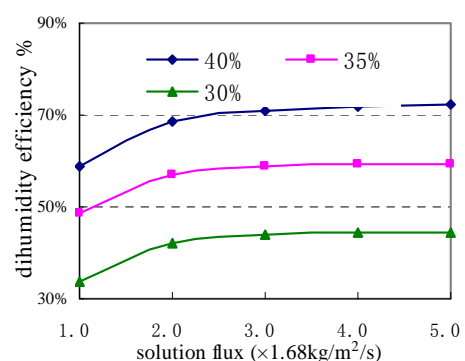
(a) the variety of outlet air humidity



(b) the variety of outlet air temperature



(c) the variety of outlet solution temperature



(d) the variety of dehumidifying efficiency

**Fig. 3 the variety of outlet parameters with inlet solution flux**

flux increasing. As the lower the solution temperature is, the less the vapour pressure of solution is, so that the impetus of mass transfer is larger, and mass

transfer factor is higher. So when the solution flux augments, the heat and mass transfer gets enhanced. When the solution flux becomes less, the curve in the

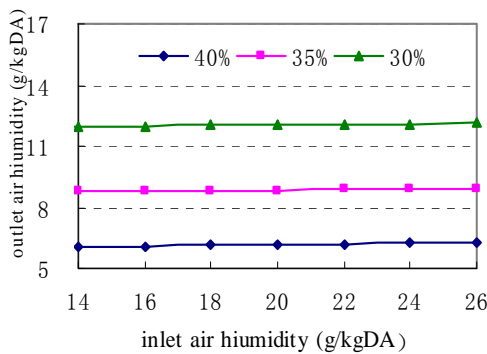
figure changes sharply; with the solution flux increasing the variety direction of the curve becomes smooth. When the solution flux is too small to moist the padding surface, The heat and mass transfer reduces at that time. With solution flux increasing, the wet ratio of padding goes up which makes the effective area of heat and mass transfer augment and the heat and mass transfer boost up quickly. When the solution flux arrives at one value, the effective area of heat and mass transfer does not increase continuously and the process of heat and mass transfer goes to stabilization. So the variety directions of the performance curves of the parameter also achieve smooth.

3.2 The affection of inlet air humidity to outlet air and solution parameter

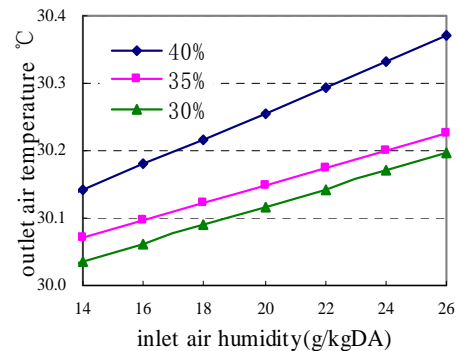
Fig. 4 describes the outlet parameters variation quantity of air and solution with the variation of inlet air absolute humidity, in the condition that air dry bulb

temperature is 34 °C, solution flux is 5.04kg/m<sup>2</sup> · s, solution temperature is 30 °C, solution concentration are 30 %, 35% and 40%. Fig. 4(a).(b) show the variation of inlet air absolute humidity hardly affects the outlet air humidity, and the outlet air and solution temperature will rise along with the augmentation of inlet air absolute humidity. According to the experiment results, the difference between the maximum and minimum of outlet air temperature is less than 2.3% of the maximum.

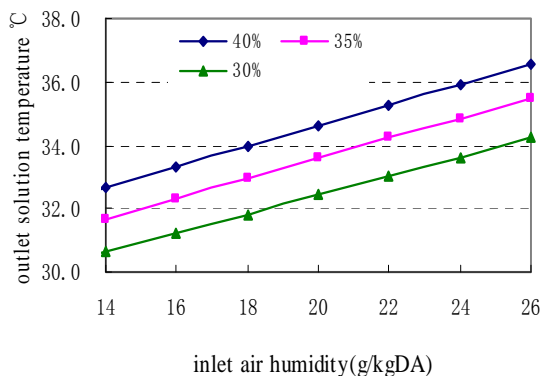
Fig. 4(c).(d) respectively describes the augment current of solution outlet temperature and dehumidifying efficiency with the increasing in inlet air absolute humidity. The larger the dehumidification quantity is, the more the potential heat released by the vapour dehumidified, so the solution temperature will rise correspondently. Usually the range of temperature rise does not exceed over 6 °C and affect hardly the average mass transfer efficiency.



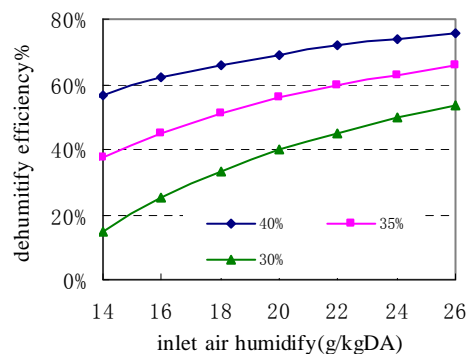
(a) the variety of outlet air humidity



(b) the variety of outlet air temperature



(c) the variety of outlet solution temperature



(d) the variety of dehumidifying efficiency

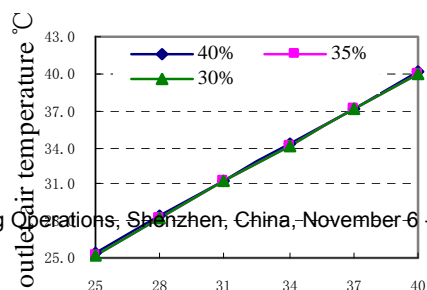
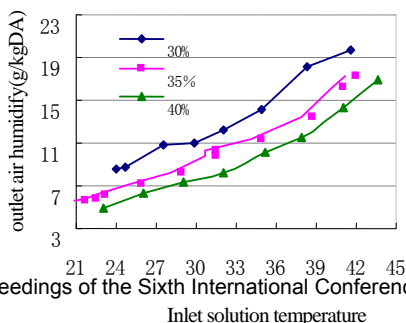
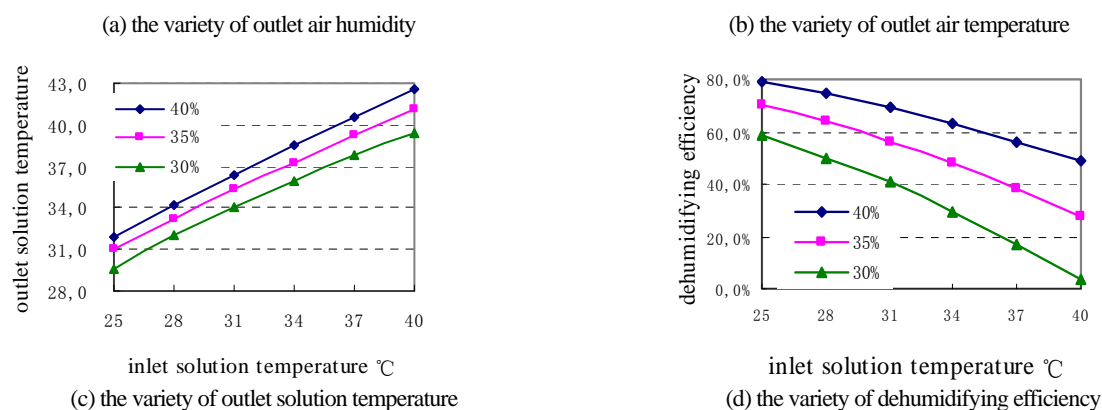


Fig.4 the variety of outlet parameters with inlet air humidity



**Fig.5 the variety of outlet parameters with inlet solution temperature**

### 3.3 The affection of solution temperature to outlet air and solution parameter

It is known from Fig. 5 that the experiment values of outlet air humidity and temperature rise obviously with inlet solution temperature rise. This denotes that along with the increase of inlet solution temperature the vapour pressure of solution augment, the impetus of mass transfer falls and the mass transfer efficiency follows to debase. When the solution inlet temperature arrives at one value, the solution dehumidifying efficiency gradually wanes till zero. For example, when solution temperature is 25°C, the dehumidifying efficiency to air exceeds over 60%; when solution temperature is 40°C, the dehumidifying efficiency to air approach to zero. If the temperature of solution rose any higher, the dehumidifier would change into a regenerator.

## 4. CONCLUSION

The experimental system constructed and operated in this study has yielded valuable information of dehumidifier. These are some quantitative data about its performance. The dehumidification system is studied by experiment in changing operating conditions. The affection currents to the variation of each outlet parameter

[4] petrification of China, 1998, (In Chinese)

[5] Guangli Zhang. The dehumidification equipment

value are obtained by changing the inlet air and solution parameter of the dehumidifier. The inlet air parameter such as air flow rate, dry bulb temperature, humidity etc hardly affects to the outlet air parameter, but the solution temperature, ratio of the air and solution, solution concentration have biggish affection to the outlet air parameter. So as the outlet air temperature and humidity have larger dependence to the desiccant solution, the selection of parameter work point in the moment of dehumidifying tower design must pay enough attention.

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