

# Investigation on the Regeneration Performance of a New Mixed Liquid Desiccant Solution in Falling Film Regenerator †

Tao Wen <sup>1</sup>, Dan Zhong <sup>2</sup>, Yuanhao Wang <sup>2</sup> and Yimo Luo <sup>1,\*</sup>

<sup>1</sup> Shenzhen Institute, Peking University, Shenzhen 518057, China; wentao@nuaa.edu.cn

<sup>2</sup> Zhuhai Da Hengqin Science and Technology Development, Co., Ltd., Zhuhai 519000, China; dzhong@peacockedu.com (D.Z.); yhwang@peacockedu.com (Y.W.)

\* Correspondence: luoyimo@gmail.com; Tel.: +86-0755-2698-4814

† Presented at the Economy, Sustainable Development and Energy International Conference (ESDEIC), Edinburgh, Scotland, UK, 25–27 June 2018.

Published: 21 November 2018

**Abstract:** The present study firstly developed a new kind of mixed liquid desiccant for the purpose of causticity reduction on metal based regenerator. The formula of the mixed liquid desiccant is 25% LiCl + 39% hydroxyethyl urea + 36% water. Experimental results show that the causticity of the mixed solution is much less severe than that of conventional LiCl solution. The regeneration rate increases with the increase of air flow rate and solution temperature and decreases with the increase of air inlet humidity. The air temperature and solution flow rate has negligible influence on the regeneration performance. The present study provides a practical alternative for the selection of liquid desiccant and also give useful guidance for the design of regenerator.

**Keywords:** mixed liquid desiccant; corrosion; electrochemical test; falling film

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## 1. Introduction

Metal corrosion caused by the utilization of liquid desiccant, such as LiCl and LiBr solution, has been observed in the liquid desiccant cooling system (LDCS) by previous researchers. In order to overcome or alleviate the causticity of liquid desiccant, some endeavors have been made. Some scholars adopted another widely used surface treatment process of anodizing for an aluminum based plate regenerator. Some researchers tried to replace the metal by plastic due to its excellent anti-corrosion performance [1,2]. However, the wettability, structure strength and manufacture technology are all considerable issues when adopting plastic as the material. Another promising way to solve the problem of corrosion is based on the modification of liquid desiccant. Some effects have also been made on this respect. LiNO<sub>3</sub> was regarded as a promising candidate for the salt solution by Luo et al. [3]. The mixed liquid desiccant with the combination of LiBr solution and organic salts of sodium and potassium was firstly put forward by Donate et al. [4].

Concluded for the abovementioned literature review, one can see the effects to overcome or alleviate the corrosion of liquid desiccant is insufficient. What is more, a lot of study just considered the vapor pressure measurement rather than the dehumidification or regeneration identification. As a result, the present study developed a new kind of mixed liquid desiccant by introducing the hydroxyethyl urea into the LiCl solution for the purpose of causticity reduction.

## 2. Comparison between Corrosion Behavior

The electrochemical test sample was made of stainless steel which is the same material as that for regenerator in present study. The measured curves for the 35% LiCl solution and the mixed liquid desiccant were shown in Figure 1. After data processing, it is found that the self-corrosion currents is  $0.2265 \mu\text{A}/\text{cm}^2$  and  $6.799 \mu\text{A}/\text{cm}^2$  for the mixed solution and 35% LiCl solution respectively. For potential, the values are  $-0.25 \text{ V}$  and  $-0.57 \text{ V}$  respectively. According the judging criteria, it is clear that the causticity has been greatly reduced by the adoption of the new mixed liquid desiccant.

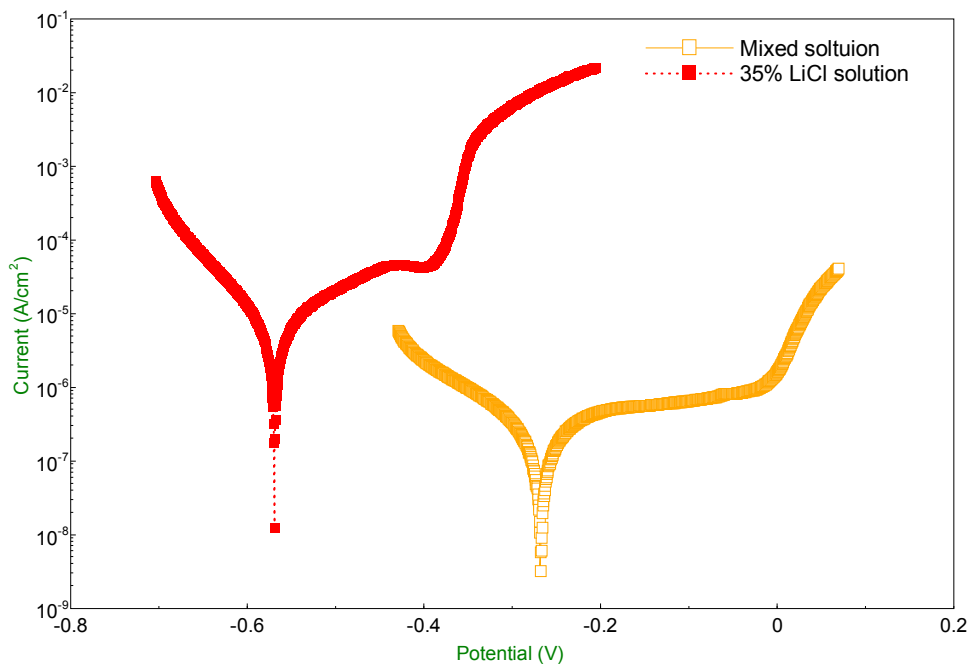


Figure 1. Polarization curves for stainless steel in different solutions.

## 3. Experimental Method

The experimental system to investigate the regeneration performance for both 35% LiCl solution and the new mixed solution is shown by Figure 2.

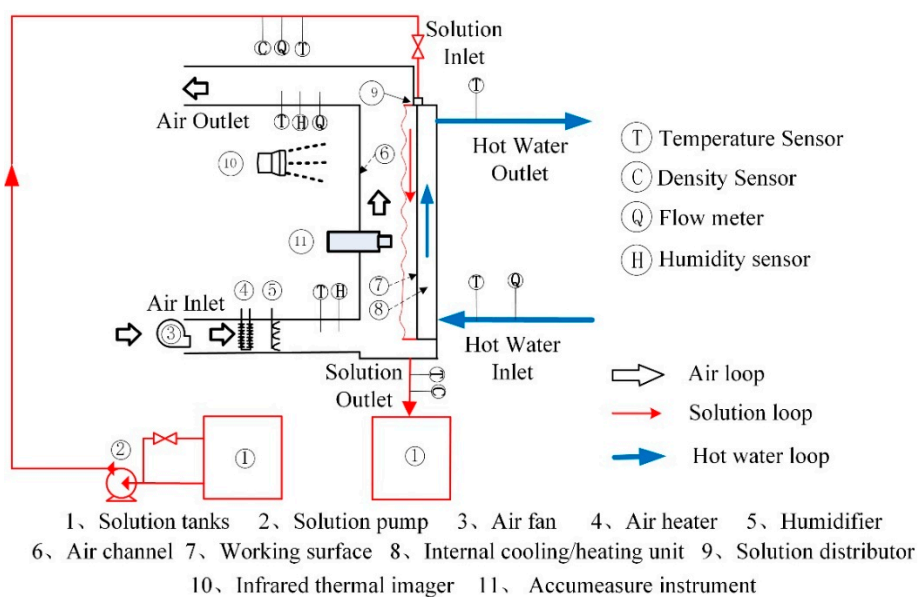


Figure 2. Schematic diagram of the test system.

The regeneration rate was chose to be the performance index to evaluate the regeneration characteristics in present study. The definition for it is shown as follows:

$$\Delta m = G_a (d_{a,out} - d_{a,in}) \tag{1}$$

#### 4. Results for Regeneration and Discussion

##### 4.1. Influence of Air Flow Rate

Figure 3 presents the influence of air flow rate on regeneration performance. It is clear that the regeneration rate increases with the increase of air flow rate. When the air flow rate increases from 0.023 kg/s to 0.07 kg/s, the regeneration rate also increases from 0.05 g/s to 0.111 g/s obviously for the mixed solution. The explanation for the ascending trending is that with the increase of the air flow rate, the mass transfer coefficient between air and solution also increases. Bigger mass transfer coefficient corresponds to higher regeneration rate.

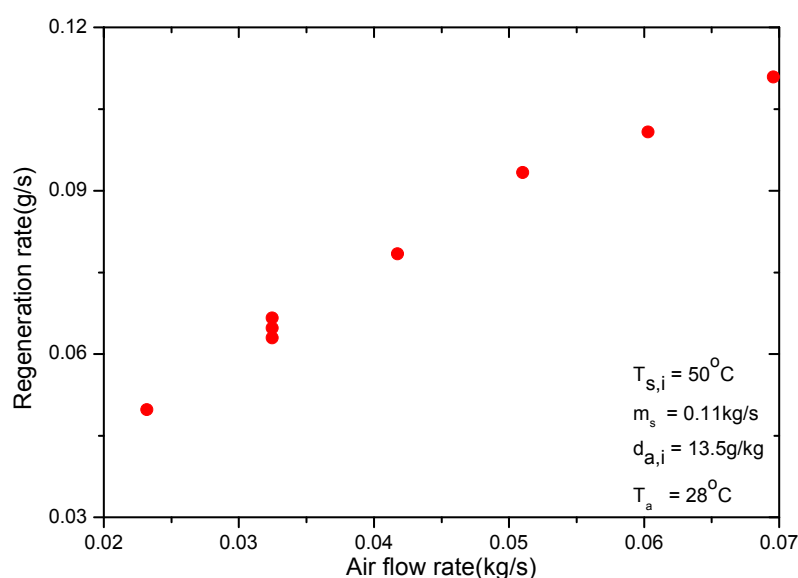


Figure 3. Influence of air flow rate on regeneration.

##### 4.2. Influence of Air Temperature

Figure 4 gives information on the regeneration rate of mixed liquid desiccant under the air temperature ranging from 28 °C to 36 °C. It is obvious that the regeneration rate maintains almost unchanged even though the air temperature has 8 °C increment. The values for regeneration rate fluctuate around 0.09 g/s and 0.084 g/s under different air temperatures. The stable trend of the regeneration rate can be attributed to the ignorable influence of air temperature on the mass transfer coefficient and wetting area of falling film on regenerator.

##### 4.3. Influence of Air Humidity

From Figure 5, the regeneration performance under various air humidity can be obtained. In Figure 5, the air humidity increases from 12.5 g/kg to 21.2 g/kg. Correspondingly, the regeneration rate decreases from 0.097 g/s to 0.032 g/s for the mixed liquid desiccant. This is caused by the fact that, when the inlet humidity of air has an increment, the mass transfer driving force which is the difference between the equivalent absolute humidity content of solution and air has a decrement accordingly. Smaller mass transfer driving force will certainly lead to smaller regeneration rate.

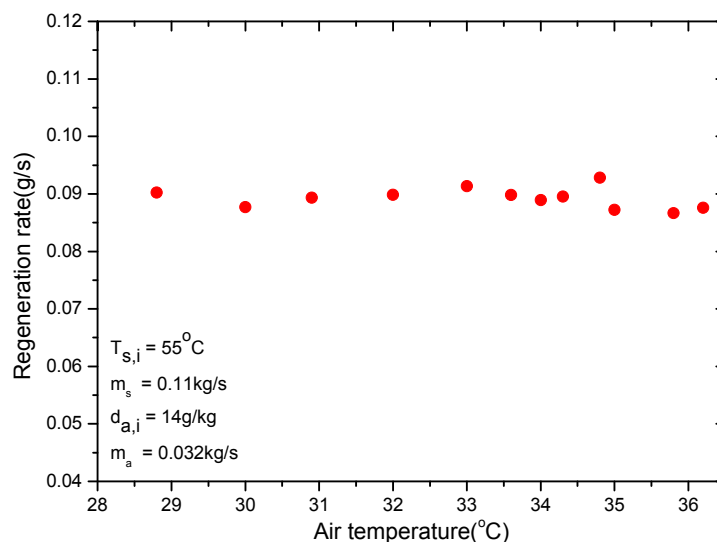


Figure 4. Influence of air temperature on regeneration.

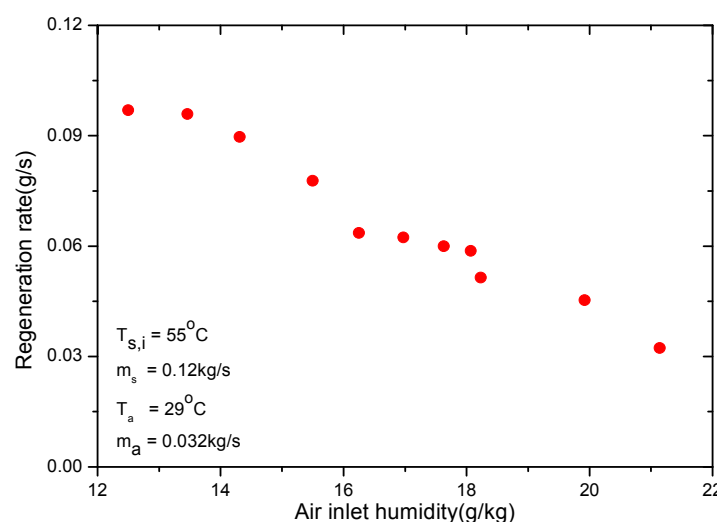


Figure 5. Influence of air humidity on regeneration.

#### 4.4. Influence of Solution Flow Rate

The experimental results for regeneration rate under different solution flow rates are presented in Figure 6. Different from the increment of mass flow rate from 0.075 kg/s to 0.144 kg/s, the regeneration rate almost keeps around a certain value. For the present mixed solution, the values are 0.064 g/s as shown in Figure 6. Even though the mass flow rate of solution has a nearly two times increment, it has little effect on the mass transfer driving force during regeneration. As a result, the regeneration rate keeps almost constant under different solution flow rates.

#### 4.5. Influence of Solution Temperature

Figure 7 describes the regeneration performance of the mixed liquid desiccant at different solution temperatures. When the solution temperature increases from 48 °C to 55 °C, the regeneration rate also increases from 0.069 g/s to 0.114 g/s which is caused by the increment of mass transfer driving force. The vapor pressure of liquid desiccant increases with the increase of solution temperature. At higher solution temperature, the different in terms of vapor pressure between solution and air is bigger which results to greater mass transfer driving force.

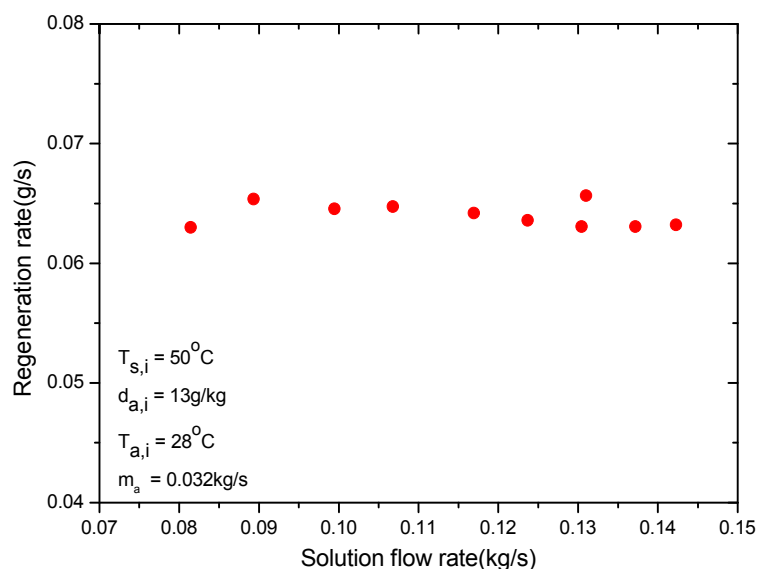


Figure 6. Influence of solution flow rate on regeneration.

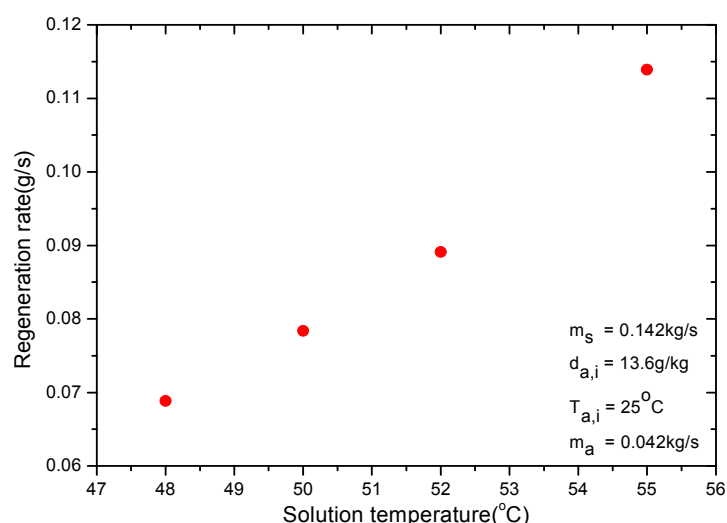


Figure 7. Influence of solution temperature on regeneration.

## 5. Conclusions

The present study developed a new mixed liquid desiccant with the formula of 25% LiCl/39% hydroxyethyl urea/36% water. The corrosion behavior of it was measured by electrochemical method. The regeneration rate of it under various working conditions was also investigated. Some main conclusions are drawn as follows: (1) The corrosion of the new mixed solution is proved to be less severe than that of the salt liquid desiccant, which is caused by the lower concentration of LiCl in the whole mixed liquid desiccant. (2) The regeneration rate of the mixed liquid desiccant increases with the increase of solution temperature and decreases with the increase of air inlet humidity resulting from their direct influence on mass transfer driving force. The regeneration rate increases with the increase of air flow rate which is caused by the increment of mass transfer driving force at high air flow rate. (3) The air dry bulb temperature and solution flow rate has negligible influence of regeneration performance as their ignorable effect on both mass transfer coefficient and wettability of falling film.

**Author Contributions:** T.W. and Y.L. conceived and designed the experiments; D.Z. and Y.W. performed the experiments; T.W. and Y.L. wrote the paper.

**Acknowledgments:** The work described in this paper was supported by National Science Foundation of China (Grant No. 51706003) and Shenzhen Peacock Plan (KQTD2015071616442225). The authors appreciated the financial supports.

**Conflicts of Interest:** The authors declare no conflict of interest.

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