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# Enhanced heat and mass transfer in alternating structure of tubes and longitudinal trough mesh packing in lithium bromide solution absorber

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ABSTRACT

For enhancing the vapour absorption in LiBr solution systems, a novel absorber with tube and mesh packing alternating structure is designed and investigated. Stainless steel mesh screens are folded as the longitudinal trough mesh packing, and inserted to the gaps of horizontal tubes to make the absorbent flow through the tube and mesh packing regimes successively, thus forming an alternating heat and mass transfer absorption process. Experimental investigation is conducted to characterize the absorption performance of the absorption bodies of this alternating structure and conventional horizontal coils. The results show that the average mass transfer rate and cooling load are increased by 17.2% and 6.23% respectively, which confirms that the alternating structures can promote the absorption. The mesh packing provides extended absorption area, slows down the flow and well mingles the solution, which are all beneficial for vapour absorption.



# Amélioration du transfert de chaleur et de masse grĝce à une structure alternée de tubes et de creux longitudinaux remplis de mousse métallique pour une solution au bromure de lithium

*Mots clés :* Amélioration de l'absorption ; Transfert de chaleur et masse ; Systèmes de solution au LiBr ; Creux longitudinaux remplis de mousse métallique ; Absorbeur alternatif

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**Nomenclature**

| | |
|---|---|
| A | area, $m^2$ |
| G | mass flow rate, Mass absorption rate, kg $s^{-1}$ (kg $h^{-1}$) |
| Q | absorber cooling load, W (kW) |
| $T$ | temperature, K |
| $U$ | overall heat transfer coefficient, W $m^{-2}\cdot K^{-1}$ |
| $V$ | volume flow rate, $m^3$ $s^{-1}$ |
| X | concentration |
| $c$ | specific heat, J $kg^{-1}\cdot K^{-1}$ |
| $h$ | heat transfer coefficient, W $m^{-2}\cdot K^{-1}$ |
| $l$ | horizontal tube length, m |
| $n$ | column number |
| $p$ | steam pressure, Pa (kPa) |
| $r$ | radius of serpentine coil, m |

*Greek symbols*

| | |
|---|---|
| $\Gamma$ | solution sprinkle density, kg $m^{-1}\cdot s^{-1}$ |
| $\Delta T$ | logarithm mean temperature difference, K |
| $\delta$ | absolute error of the parameters |
| $\varepsilon$ | relative error of the parameters |
| $\lambda$ | thermal conductivity, W $m^{-1}\cdot K^{-1}$ |
| $\rho$ | density, kg $m^{-3}$ |

*Subscripts*

| | |
|---|---|
| a | absorption side |
| c | Concentrated solution |
| d | dilute solution |
| i | inlet, internal |
| o | outlet, outside |
| s | saturated |
| w | cooling water side |

## 1. Introduction

The absorption of water vapour by LiBr solution is a heat and mass transfer process widely employed in refrigeration and air conditioning systems driven by solar energy or waste heat. Due to the low heat and mass transfer coefficient, most of the absorption bodies present huge volume and necessitate lots of metal material and the system performances are also restricted (Killion and Garimella, 2003). It is of great importance to improve the performance of the LiBr solution absorbers.

Several methods have been proposed to enhance the heat and mass transfer of LiBr solution absorption process, such as modifying the absorber structure, improving the LiBr solution by adding additive or accelerant (Park et al., 2001; Kim and Ferreira, 2009), and optimizing the working process, etc. Fujita (1993), Isshiki and Ogawa (1996), Miller (1999), Chen et al. (2004a, 2004b) improved respectively the absorption properties by using the complex heat and mass transfer structure surfaces. Islam et al. (2003), Cui et al. (2009) and Chen et al. (2008) proposed successively the film-inversion schemes. Selim and Elsayed (1999) and Sieres et al. (2009) respectively studied adiabatic absorption with the packing structure applied in ammonia adsorption systems. Shen and Qiao (2005) and Wang et al. (2007) studied respectively separate pre-cooler plus adiabatic absorber for LiBr solution absorption refrigeration system. However, the incidental crystallization of LiBr solution at high concentration and low temperature forces the precooling process with larger flow rate and higher temperature of solution, thus the concentration of the LiBr solution has to be reduced and the absorption driving force is declined in the packing regime, which limits the efficiency of adiabatic LiBr solution absorbers.

The mesh packing structure, with knitting latitude and longitude metal threads, forms innumerable capillaries and coarse surface to increase perturbation, and also constructs a perfect dual-side exposition adiabatic mass transfer surface for the vapour absorption of the LiBr solution film. To further enhance the absorption, the LiBr absorption system needs further perfection for better performance. Therefore, a novel absorption absorber based on horizontal tube bundle and mesh packing inserts is designed. The stainless steel mesh screens are folded as longitudinal trough packing inserted to the gaps of the horizontal tubes to construct a tube and mesh packing alternating absorber (TPA). In this alternating structure, the temperature and concentration of the LiBr solution vary periodically along with the LiBr solution flows on the tube surfaces and mesh packing layers, thus the crystallization is avoided and heat and mass transfer is enhanced. Furthermore, the mesh packing layers occupy no additional space and can mix the solution well. They can also be taken as the film guiders between adjacent tube surfaces as mentioned in literature (Chen et al., 2012), which are beneficial for the heat and mass transfer.

In this paper, heat and mass transfer performance of TPA absorber is characterized and compared with that of the horizontal serpentine tube absorber (TA) under the same experimental conditions. Experimental data are also compared with the results of theoretical models of the horizontal tube absorber (Jeong and Garimella, 2002; Killion and Garimella, 2001; Kirby and Perez-Blanco, 1994; Kyung et al., 2007a, 2007b; Papaefthimiou et al., 2012).

## 2. Experimental setup and data reduction

### 2.1. The structure of the tube and mesh packing alternating structure absorption body

Fig. 1(a) shows the schematic of the designed absorption body in the experiment. Four serpentine tubes with the inner and outer diameter of 10 mm and 12 mm are stagger arranged. Each serpentine tube has 8 horizontal tube sections with the horizontal length of 480 mm and tube pitch of 50 mm. Forty-grits stainless steel mesh screens with wire diameter of 0.2 mm are folded as longitudinal troughs of the waved packing inserting between the horizontal tubes as shown in Fig. 1(b). The longitudinal troughs of the waved packing are parallel to the horizontal tubes and the accumulated solution could be guided to the next tubes by gravity. The ends of the