Characteristics of the Membrane utilized in a Compact Absorber for Lithium Bromide-Water Absorption Chillers

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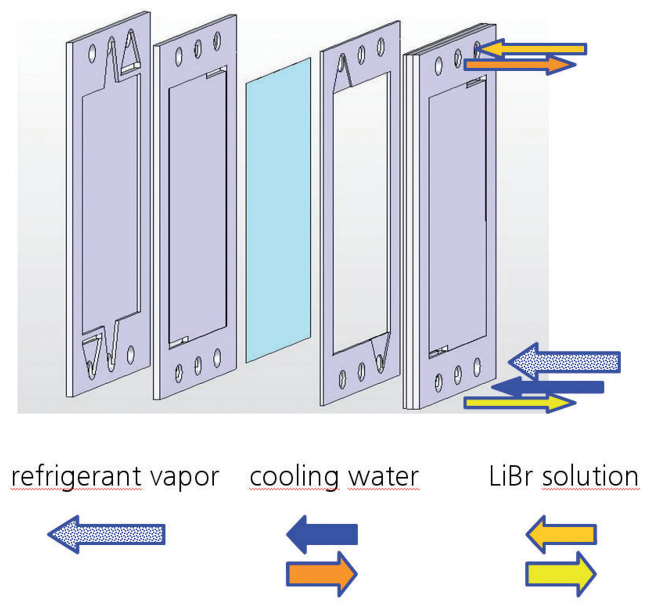
Absorber Concept and Objectives

In view of the current discussion on CO_2-emission reduction and the escalating energy prices conservation of primary energy is absolutely essential. The increasing market of small capacity chillers for **residential climatisation** provides an excellent opportunity to use **thermally driven cycles** such as **lithiumbromide/water absorption** machines instead of compression cycles. An important need to facilitate the market acceptance is reduction of plant volume by developing new strategies.



Introducing **membrane technology** to absorber design could replace conventional shell and tube absorbers in order to achieve a high compact design: flat **hydrophobic microporous membranes** form narrow solution and vapor channels, providing a large exchange surface in a small volume, similar to fuel cell stacks or plate type heat exchangers.

Fig. 1: Schematic Membrane Absorber Design

Analytical Model

The FORTRAN Code AHC-SIM allows calculation of heat and mass transfer in an absorber with **microporous hydrophobic** membranes.

Given the

- size and tortuosity of the membrane pores
- porosity and thickness of the membrane
- thermal properties of aqueous LiBr solution
- basic process parameters

the refrigerant vapor flux, heat transfer coefficients and energy balances are obtained. The calculation of vapor flux is based on the **dusty-gas model** for transport through porous media via a **Knudsen diffusion** mechanism:

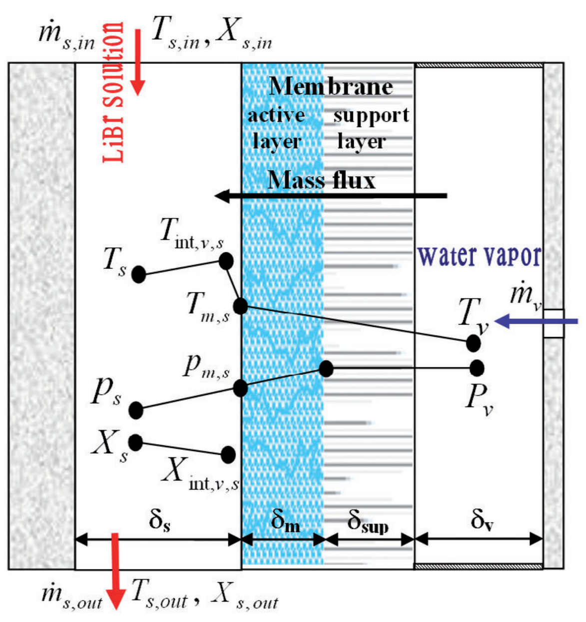


Fig. 2: Heat and mass transfer in a membrane absorber cell

$$J_{H_2O} = k_{ov}\left(P_v - p_s\right), \quad \text{where} \quad k_{ov} = \left(\frac{1}{k_m} + \frac{1}{k_{\mathrm{int},v,s}}\right)^{-1},$$

$$k_m = \frac{\varepsilon}{\tau.\delta_m}\frac{M_{H_2O}}{RT_m}D_K \quad \text{and} \quad D_k = \frac{d_{pm}}{3}\sqrt{\frac{8RT}{\pi.M_{H_2O}}}$$

Experimental Results

An experimental set up shown schematically in Fig. 3 is used to investigate the absorption of water vapor into LiBr solution through different membranes **under vacuum conditions**. The test cell was designed to create a **thin film of LiBr solution** with the channel depth set by gasket rings.

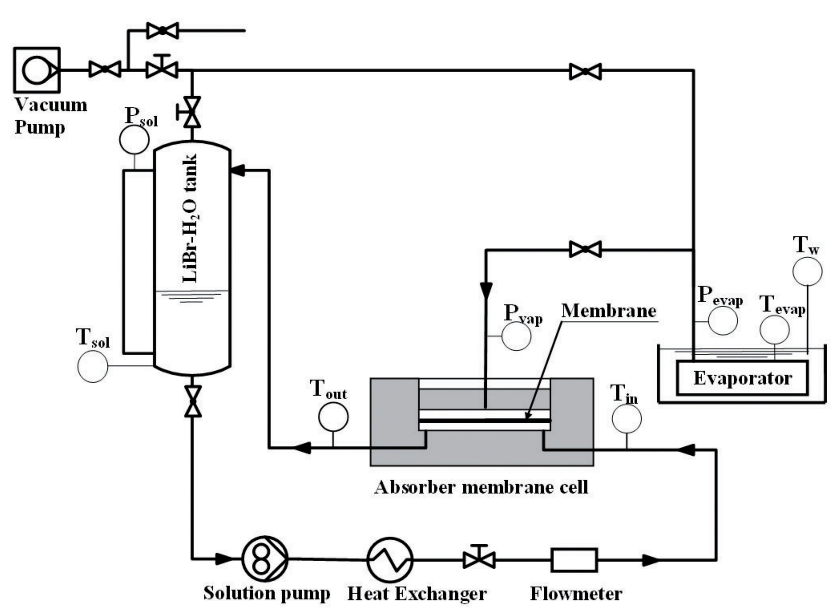


Fig. 3: Schematic diagram of the experimental apparatus

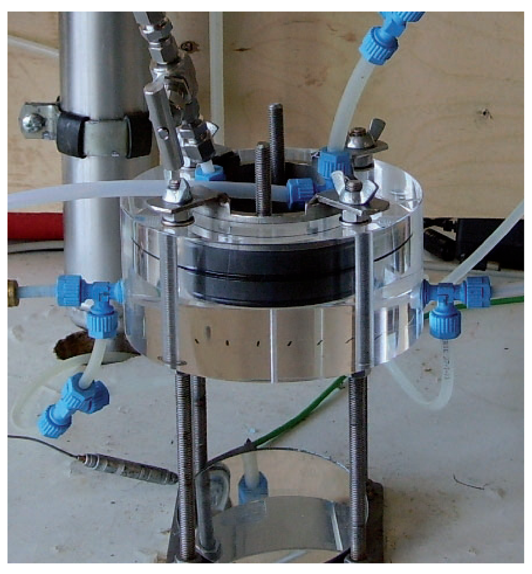


Fig. 4: Membrane test cell

Parameters of the experiments:

- solution concentration in the range 50.8 to 54.0 wt% LiBr
- temperature 24 to 29 °C
- solution flow 70 to 200 ml • min-1
- evaporator temperature 16 to 25 °C

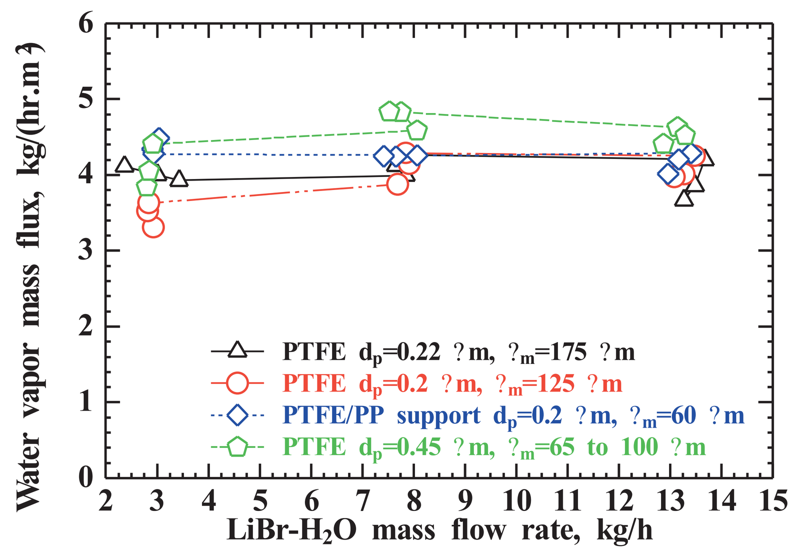


Fig. 5: Measured values of water vapor flux for different membranes

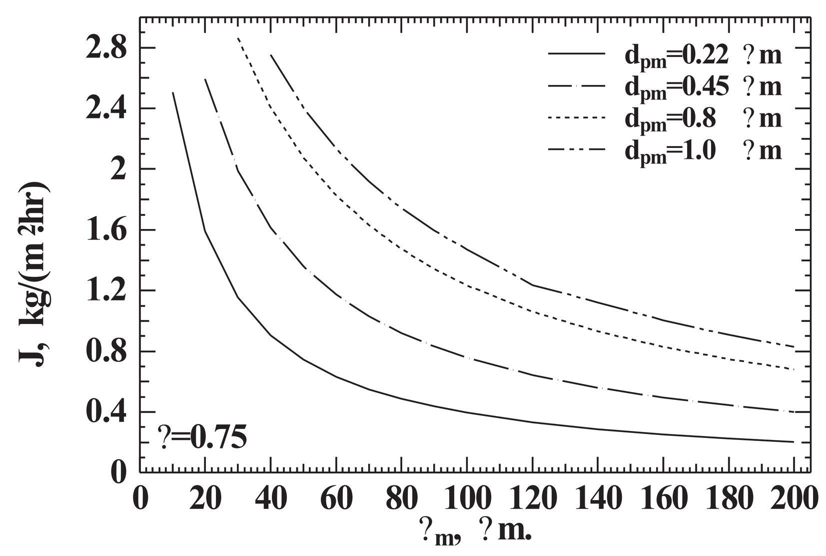


Fig. 6: Effect of membrane thickness on the water vapor flux

The results indicate that the water vapor flux increases with an increase of the membrane pore size and decreases with increasing active membrane layer thickness.

- water vapor flux is primarily function of the **partial vapor pressure difference** across the membrane
- it is not significantly affected by the solution mass flow rate
- membrane mass transfer resistance is rather constant and **dominates the overall mass transfer** resistance
- thin bulk solution film and high Re necessary for limited mass transfer resistance

Validity of the model results

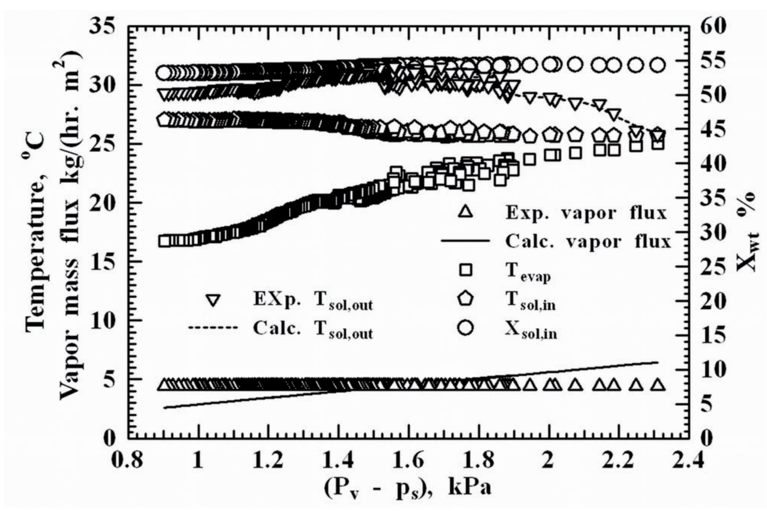


Fig. 7: Comparison of calculated values with corresponding measured data

The experimentally measured values of water vapor flux as a function of the driving potential (vapor pressure difference) are in **good accordance** with the corresponding values obtained from the simulation model (Fig. 7). Furthermore, the model was **validated with the working pair LiCl-water** and published measured data.

Conclusions and Outlook

Commercially available, porous hydrophobic membranes are suitable for **membrane absorbers in absorption chillers**. The refrigerant (water) **vapor flux** into a thin film of lithium bromide/water solution obtained from the experiments is calculated to **1.4 kg m-2 hr-1**. It can be assessed with the model for any process conditions.

Desired characteristics of membranes:

- having high permeability to water vapor
- being hydrophobic to the liquid solution
- pore size being rather small to avoid capillary condensation of vapor inside the pores and pore blocking
- having narrow pore size distribution to obtain **high liquid entry pressure** (LEP) to avoid pore penetration
- therefore **pore size** preferably between **0.45 to 10 µm**, with lower edge recommended
- **porosity up to 80 %**
- membrane **thickness up to 60 µm**, with additional highly porous **support layer** on the vapor side
- commercially available
- low price

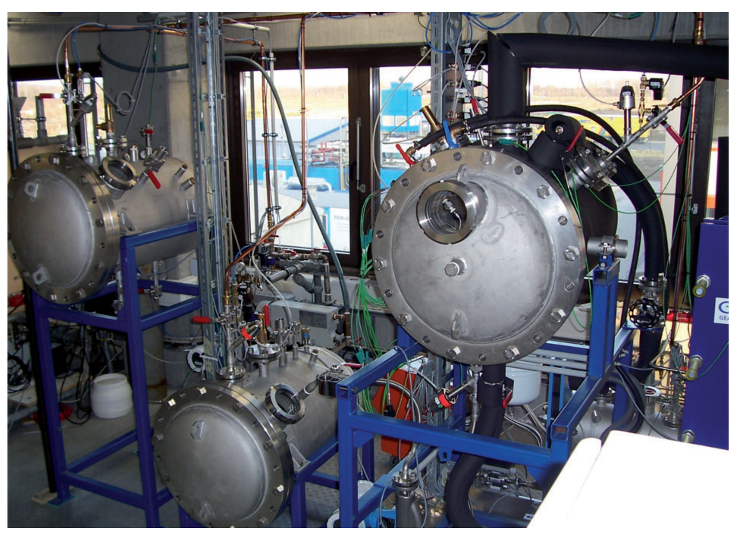


Fig. 8: UMSICHT Heat pump test bench

Based on membrane characterisation measurements a **full size membrane absorber prototype** is under construction and will be investigated in the **heat pump test bench** at UMSICHT. Afterwards integration of a **complete cycle** is intended.

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