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Concentration Measurement Technique for Aqueous Lithium Bromide Solution in Vapor Absorption Air Conditioning Systems

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ABSTRACT

For the purpose of establishing the in plant measurement technique of the absorbent concentration in solar vapor absorption air conditioning system, the relation between concentration, conductivity and temperature were experimentally studied using aqueous solutions of LiBr.

The measurements have been performed with the aid of a commercially available conductivity meter and electrode with built-in temperature probe (K=10).The measurements cover the vapor absorption cycle working temperature range (20 to 60°C) and concentration range (45 to 65%) for the lithium bromide aqueous solution.

The test results of the experiment showed that, this technique can measure the lithium bromide solution concentration accurately, conveniently and quickly.

Keywords: *Absorption, absorber, Conductivity, Concentration*

I. INTRODUCTION

Lithium Bromide (LiBr) is a white powder with a bitter taste soluble in water, alcohol and glycol. It is used as an operating medium for absorption air-conditioning and industrial drying systems due to its very hygroscopic property. For the continuous control of any absorption system, it is important to monitor the properties of the binary solution at different points in the cycle. The concentration of the water/lithium bromide solution is one of the most important parameters which play a significant role on the performance of such system.

As the lithium bromide is extremely hygroscopic [Lide et al., 1994], it is important to follow a working procedure to ensure that no moisture from the atmosphere is absorbed unintentionally when preparing the measuring samples to correctly measure its concentration.

There are three techniques available to measure the concentration of the binary water/lithium bromide solution; the most commonly used method is the titration method (Herold et al.1996), which can give a high accuracy when the procedure is performed by an experienced and skilful researcher. The drawback of this method is that it tends to be time consuming, as it requires drawing a sample from the system solution. The second method is the measurement of the electrolyte conductivity of the binary water/lithium bromide solution which give accurate results and the third method is the continuous measurement of concentration using radioactive tracer detectors which is the most expensive technology (Horn, 1969).

Swallow &Smith (1998) presented a mechanically aided absorber comprising of several rotating disks semi-submerged in a solution trough. Due to disk rotation, the thin solution film formed on the disk surfaces can be constantly refreshed and mixed.

Choudhury et al. (1993) modeled the absorption heat and mass transfer in laminar films falling over horizontal tubes. The major differences between their model and the model by Andberg and Vliet [45] are that they assumed constant fluid properties and the tube to be isothermal.

The design of air conditioning systems which use aqueous lithium bromide solutions requires accurate thermal conductivity data. A conductivity meter is used to determine the conductivity of the lithium bromide solution at different temperatures and concentrations.

II. MEASUREMENT TECHNIQUE

The working ranges investigated in this study for vapor absorption systems based on water/lithium bromide are (45-65%) for the concentration of the lithium bromide in the binary solution and (20-60^{o}C) for the temperature of the solution. The samples of the binary solution at different concentrations are prepared in a closed glass beaker and heated in a constant temperature water bath. A commercially available conductivity meter with a built-in temperature probe is then used to measure the conductivity of the solution at different temperature.

The reaction of the lithium bromide powder and water is exothermic; this produces a significant rise in the temperature of the solution. The temperature of the solution was controlled by a thermostatically regulated water sink to the desired value. The aim of these measurements is to find the concentration of the lithium bromide solution which changes inside the absorber by absorbing vapor from the evaporator through time. The conductivity of the solution had to be first measured with the temperature for a constant concentration and then draw a correlation curve between the conductivity and the temperature at different concentration.

III. SAMPLE PREPARATION:

The samples were prepared from a pure dry lithium bromide powder (99.999%) and deionised water. A digital mass balance was used to measure the masses of the lithium bromide that will be added to the constant distilled water to have the different concentrations.The group of solutions will have different concentrations of range (45-65) % of lithium bromide.

The following steps were conducted to draw the correlation curve between conductivity and the temperature for the different concentrations of lithium bromide solution:

- Prepare an amount of distilled water.
- An accurate calculated amount of distilled water is added to the calculated grams of the lithium bromide salt in a beaker to have the required concentration of the lithium bromide solution.
- The samples of the binary solutions are heated using the magnetic stirrer for a constant temperature and then left to be cooled with the time through immersing the samples in constant temperature water.
- A conductivity meter with a built-in temperature probe is immersed in the beaker to measure the conductivity and temperature of the solution.
- The conductivity and the temperature for a constant concentration are recorded and listed in table (1).
- Draw a curve of conductivity versus temperature at constant concentration as shown in figure (1).

IV. CONDUCTIVITY MEASUREMENT

For a cell of a uniform cross section (A), with electrodes at either end separated by distance (l), the conductivity (K) is related to the conductance (G), by equation (5.6) and has the units (Ω-1m-1 or Sm-1). (Hamann et al. 1998)

V. APPARATUS

In principal, the measurement of the conductivity could be carried out in a cell, with rectangular electrodes of known area A m2 positioned l m apart. However, in practice a number of complicated corrections would have to be made for getting the exact value of the conductivity. Rather than doing this for all measurements, use is now made of definitive conductivity measurements for certain standard solutions carried out under very carefully controlled conditions in specially designed cells. The digital conductivity meter required for this work must have the following characteristics:

- Displays the conductivity values in Siemens digitally.
- A very high conductivity range 0 to 19.99 S.
- Simple in operation.
- Enables both analogue and digital interfacing capability.
- High accuracy and low resolution.
- Has the capability to measure both the conductivity and temperature.
- Storing results facility.

VI. CALIBRATION

A sample of known electrolyte conductivity (e.g. 0.745 g/litre Potassium Chloride solution) has been used to calibrate the instrument. Dissolving 0.745 grams of dried Analar Grade Potassium Chloride (KCl) into 1 litre of de-ionized water. The solution has been placed into a water bath set to 25°C. When the temperature of the calibration standard solution has reached steady state, the electrode has been placed in the solution and left for 5-10 minutes. The range of 0-2000 μSiemens range on the conductivity meter has been selected, and then the reading has been adjusted to 1413 μSiemens.

VII. Data Correlation and Empirical Modeling

An extensive and thorough survey of the market led the author to conclude that Omega bench-top CDB-387 Conductivity meters were the most suitable. Conductivity ranges from 0-200 mS/cm with resolution 0.01S and accuracy ± 1%, the temperature range is 0 to 100 °C with accuracy ±0.1°C. It is also concluded that the epoxy conductivity cell model CDE-5004-ED10 with constant (K=10) and built-in temperature probe is the most suitable probe to link with the conductivity meter.

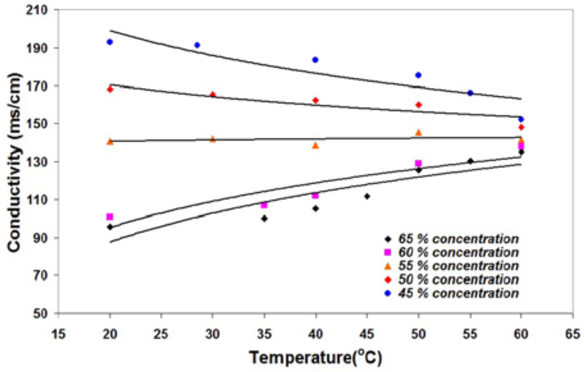


Figure 1: Water-Lithium Bromide Temperature vs. Conductivity for Different Concentrations

Table 1: Electrolyte Conductivity for Different Concentration

0.45		0.50		0.55	
T(^{O}C)	C	T(^{O}C)	C	T(^{O}C)	C
60	152	60	148	60	142
55	166	50	160	50	145
50	175.4	40	162.4	40	138
40	183.5	30	165.5	30	142
28.5	191.3	20	168	20	141
20	193				
0.60		**0.65**			
T(^{O}C)	**C**	**T(^{O}C)**	**C**		
60	*141.5*	*60*	*135*		
50	*145.4*	*55*	*130.5*		
40	*138.4*	*50*	*125.5*		
30	*142*	*45*	*111.7*		
20	*1403.6*	*40*	*105*		
		35	*100*		
		20	*95.5*		

The experimental data presented in table (1) shows that for a constant concentration, the conductivity decreases with temperature for concentrations up to 55% LiBr. For concentrations higher than 55%, the conductivity increases as the temperature increases. In order to develop an empirical model of the concentration as a function of temperature and conductivity of the aqueous lithium bromide solution, numerical curve fits have been produced for the experimental points of conductivity versus temperature at particular concentrations.

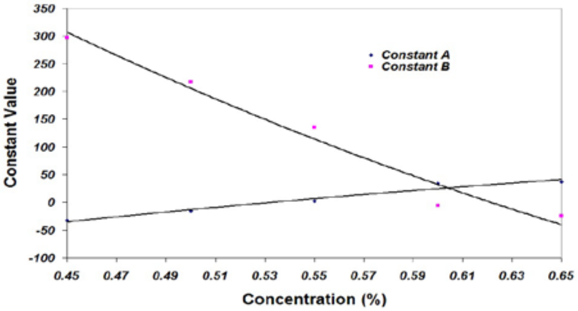
The best-fit equations are logarithmic of the form given by equation (1).

$$C = a_i \ln(T) + b_i \quad (1)$$

The values of the constants ai and bi are given in table (2) for different concentration Xi.

Table (2) constants' values for equation (5.2)

X_I%	a_i	B_i	X_I%	a_i	b_I
45%	-32.91	297.8	60%	33.81	-6.044
50%	-15.57	217.1	65%	37.30	-24.15
55%	1.83	134.9			



An equation is then constructed using the above equations to produce a relationship giving the concentration of the lithium bromide solution {X %} as a function of temperature {T, oC} and electrolyte conductivity {C, mS}. This is presented in equation (3).

$$X\% = \frac{-m + \sqrt{m^2 - 4nl}}{2l} \quad (2)$$

Where,

$$l = d_1(\ln T) + d_2$$

$$m = d_3(\ln T) + d_4$$

$$n = d_5(\ln T) - C + d_6$$

Table 3: Constants' Values for the Above Equations

d_1=-375.01	*d_2=1896*
d_3=792.17	*d_4=-3819.8*
d_5=-315.49	*d_6=1641.8*

VIII. RESULTS AND DISCUSSION

Figure 2 presents the experimental data of electrolyte coconductivity of the aqueous lithium bromide versus the temperature. These experimental data agree with the trends presented by Hamann et al. However, at higher concentrations, the conductivity rises less rapidly than expected from the extrapolation of the results; this is due to the increase of the inter-ionic interactions as the mean distance between ions decreases [5].

IX. CONCLUSIONS

- The concentration of an aqueous lithium bromide solution in a vapour absorption system can be determined by measuring the Electrolyte conductivity or the density and the temperature of the solution. Instantaneous value of the calculated concentration can be indicated using a computer driven data logger.
- By means of the Omega CDB-420 Conductivity meter and the epoxy conductivity cell model CDE-430-10-EP with constant (K-10), both thermal conductivity and temperature can be measured for the aqueous lithium bromide solution in the working range for the absorption refrigeration system. Using the equations developed by this study, the concentration of the solution can be determined with percentage accuracy ±0.5%.

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