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Analysis of Ideal Absorption Cycle with Support of Solar Energy and the Use of Working Solutions H_2O/LiBr and NH_3/H_2O

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Abstract

This paper presents of a comparison of two single-effect ideal absorption chillers lithium bromide/water and ammonia/water using like working solutions. In each part of component of the system are analyzed based on pressure, mass flow, enthalpy, concentration refrigerant and sorbent. The same cooling demand has been chosen for absorber, generator, condenser and evaporator in both cases. Selected input data, resp. the temperature gradient was selected on the basis of the most commonly used temperature gradient in practice. Used input data for both working solutions particularly affect energy efficient ratio (EER), where ammonia/water works with lower EER than working substance lithium bromide/water.The performance of generator works with higher efficiency with ammonia/water.

Keywords - solar cooling, absorption chiller, working solution

1. Introduction

During the last years, especially in summer season a demand for air-condition and cooling increases rapidly. This causes a problem, not only environmental, but social and economic, mainly because the use of air-condition and refrigeration systems are based on electric energy consumption. Solar cooling technology is environmentally friendly and contributes to a significant decrease of the CO_2 emissions which cause the green house effect. These systems are ideal for cooling hotels, office buildings, data centers and other large commercial buildings.

Solar cooling systems save money for building owners because electricity rates are often tiered, meaning that the more electricity a building uses during peak hours of operation, the higher the rate charged for that electricity. Peak hours often occur on hot sunny days when the air conditioning load is the highest. Installing a solar cooling system can result in big savings since the system reduces electricity use during the peak hours.

2. Where to Use System of Solar Cooling

- Hotels, office buildings, data centers and other large commercial buildings,
- Continuous operation system (24 hours/7 days),
- Curve of daily cooling demand copy curve of solar gain during a day, their maximum values are the same ,
- Technology is environmentally friendly ,
- The technology of solar cooling uses thermal energy obtained from solar collectors to power cooling systems,
- The system consists of the known photo-thermal (collector, storage tank, heat exchanger, control unit, distribution) and by the cooling system, which is driven by heat (see fig.1),
- In this process, the solar heat is collected and used for thermo - controlled cooling process of a building [3, 9, and 10].

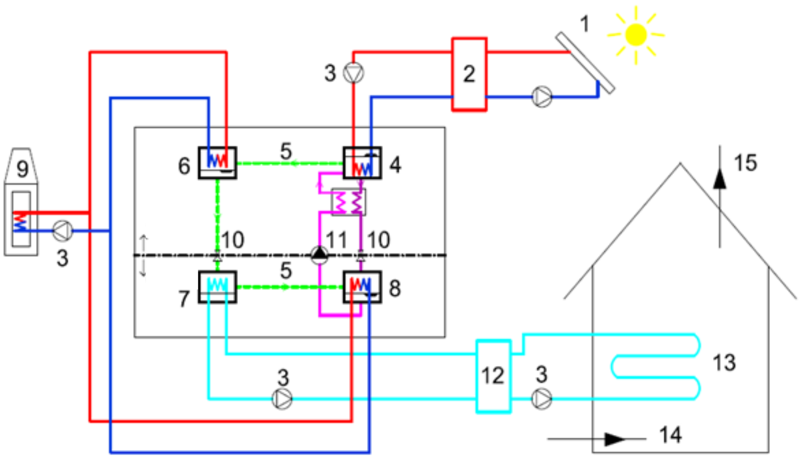

Fig. 1 The basic scheme of absorption cooling [9]

Where:
1 - collectors, 2 - thermal buffer, 3 - circulation pump, 4 - generator, 5 - cooling agent vapor, 6 - condenser, 7 - evaporator, 8 - absorber, 9 - cooling tower, 10 - expansion valve, 11 - pump, 12 - cold buffer, 13 - distribution of air,14 - supply air,15 - exhaust air.

3. Analysis of an Individual Part of the Absorption Cycle with Working Substance H_2O/LiBr and NH_3/H_2O

To be able to define and optimize system behavior under certain input conditions, we have to be able to determine in each part of the system pressure, temperature, enthalpy, concentration and mass flow of the substance, which is located. The most important step in the calculation of these quantities is to define the basic principles of a functional absorption cycle.

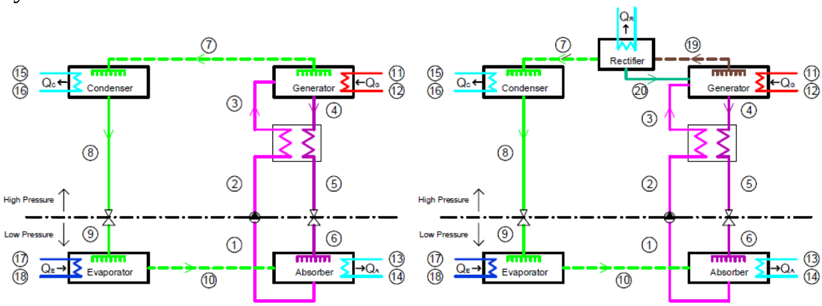

Fig. 2 The basic scheme of mathematics model a, absorption cycle b, adsorption cycle

The basic idea is that the cycle (the ideal cycle) operates with two pressure levels, which are separated by pressure - regulatory elements, i.e. circulation pump and expansion valves. It is clear from basic scheme of solar cooling that the condenser and the generator are working with the same working pressure as well as the operating evaporator and absorber at the same pressure (see fig. 2) [2,3,4].

4. Boundary Condition of the Absorption Cycle

Before analyzing the individual parts of the absorption cycle (AC), it was necessary to determine boundary conditions (see tab.1). It was important to determine the temperature on the external side of the system, where the pair of matter works with temperature gradient 12/7 ° C for the evaporator and 90/80 ° C for the generator. External temperatures of the absorber and condenser have been set up for each substance in six variants. The cooling performance of the evaporator is selected100 kW, of which we can calculate the mass flow rate [1, 2, 3, 4].

Tab.1 Absorption cycle- input data

Working substance		Variants	Input parameters			
			Absorber	Generator	Condenser	Evaporator
$H_2O/LiBr$	NH_3/H_2O	V1	28/32	90/80	28/32	12/7
		V2	28/35		28/35	
		V3	30/35		30/35	
		V4	32/36		32/36	
		V5	35/40		35/40	
		V6	35/41		35/41	

5. Input data, output data, results EER, QG

To determine the internal temperature was chosen following. The evaporator is able to operate with temperatures between 5-10 °C. The aim is to achieve the lowest possible temperature. The lower the temperature the lower will be the temperature of chilled water. The temperature 5 °C for cooling systems H_2O/LiBr is limit value, being due near to the freezing point, which is used in the system as a refrigerant. Therefore, it was considered critical value of 5 °C. NH_3/H_2O is considered of equal value, although ammonia as the refrigerant operates at temperature below -77, 7 °C [1, 2].

A selection of the temperature in the condenser was difficult. Instead of calculating the logarithmic temperature gradient there was determined fixed temperature difference between the temperature of cooling water at the inlet and the temperature in the condenser, i.e. 10 °C. Outside temperatures were chosen based on the most widely used falls in practice (see tab.1).

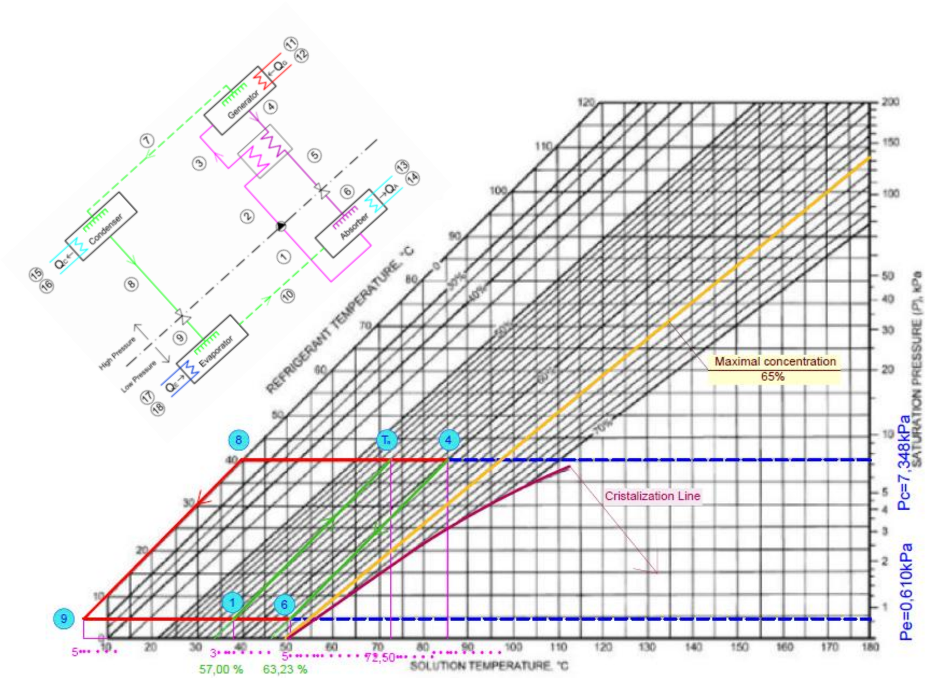

Fig. 3 Model of absorption cycle in P-x-T diagram with working substance H_2O/LiBr [3]

Determination of the temperature in the absorber is important for the concentration of LiBr in the rich solution. In this case, the absorbent is cooled with water; therefore the selected temperatures are as same as for the condenser (see tab. 1). Fixed temperature difference is 8 °C. After a previous analysis of temperatures, temperature received in the generator, which is obtained from the P-x-T graph where we got the values of pressure levels [1, 3, 4, 5, 6, 7, 8, 9].

The calculation for both working substances is very similar. In the system with working substance NH_3/H_2O is a rectifier added to the other elements of the generator, which is used for draining the condensed water vapor in the generator. Power rectifier is estimated to be 10-20 % of the power generator.

It is obvious from partial results of comparison that the single-effect ideal absorption cycle works with as same input parameters as working solution H_2O/ LiBr with a higher EER as NH_3/H_2O (see tab. 2, fig. 4).

Conversely, the same input parameters with a cooling capacity of 100 kW operate a generator with higher power (see. tab. 2, fig. 5) in NH_3/H_2O. Energy-efficient ratio (EER) we got as a share of power the system obtained (power expansion) to power given in the system (power generator).

$$EER = Q_E / Q_G \; (-) \tag{1}$$

Where:

Q_E - Performance gained system (evaporator performance) (kW).

Q_G - Performance inserted into the system (generator performance) (kW).

For interesting it is needed to show EER_P where is counted with energy of pump.

$$EER_p = Q_E / \left(Q_G + W_p\right)(-) \tag{2}$$

Where:

W_P - Pump input power (kW).

The next computation is used as a control power balance method.

$$Q_E + Q_G = Q_C + Q_A \tag{3}$$

Where:

Q_E - Evaporator performance (kW),
Q_G - Generator performance (kW),
Q_C - Condenser performance (kW),
Q_A - Absorber performance (kW).

Tab.2 Absorption cycle - EER, QG

Working substance		Variants	EER		QG	
			$H_2O/LiBr$	NH_3/H_2O	$H_2O/LiBr$	NH_3/H_2O
$H_2O/LiBr$	NH_3/H_2O	V1	0.824	0.486	121.296	171.315
		V2	0.831	0.582	120.367	143.820
		V3	0.811	0.483	123.361	172.409
		V4	0.767	0.462	130.399	180.223
		V5	0.879	0.688	113.803	121.176
		V6	0.879	0.688	113.803	121.176

The Fig.4 shows that temperature of generator directly influences energy efficient ratio of absorption cycle with two different substances. From the figure is clear that EER is higher with $H_2O/LiBr$.

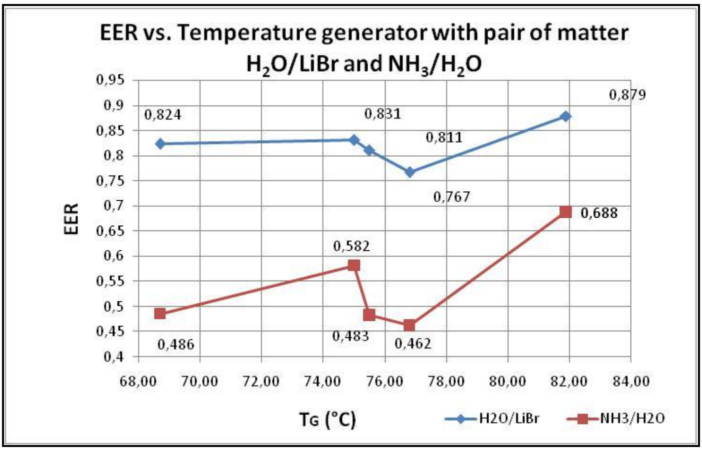

Fig. 4 Comparison EER vs. Temperature of generator working solution $H_2O/LiBr$ and NH_3/H_2O

The Fig.5 shows that performance of generator with the use of the same temperature gradient into absorber and generator is higher using working solution NH_3/H_2O.

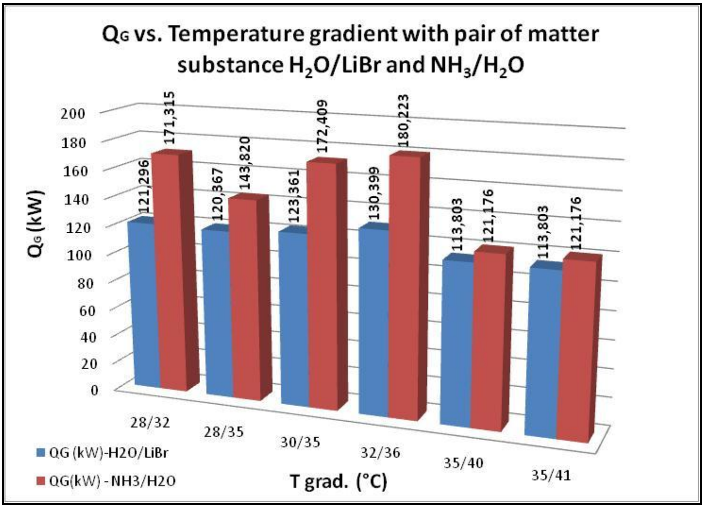

Fig. 5 Comparison Q_G vs. Temperature gradient working solution $H_2O/LiBr$ and NH_3/H_2O depends on temperature gradient for absorber and condenser

From the Fig.6 is obvious that EER of working solution $H_2O/LiBr$ is higher as working solution NH_3/H_2O.

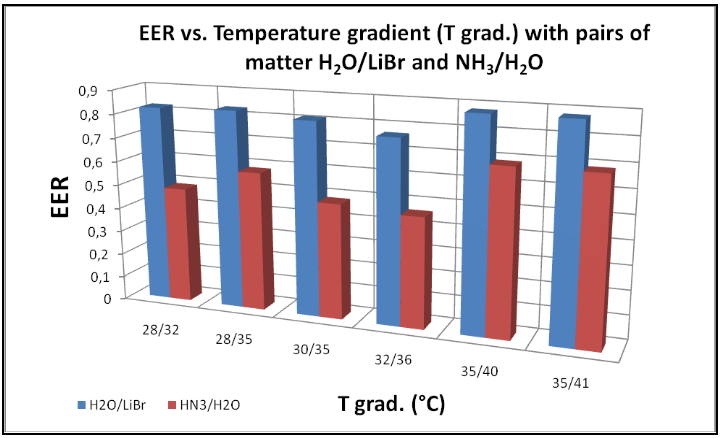

Fig. 6 Comparison EER vs. Temperature gradient working solution $H_2O/LiBr$ and NH_3/H_2O depends on temperature gradient for absorber and condenser

6. Conclusion

The basic consideration was to compare two single-effect absorption cycles with the same input parameters. In tab. 2 and figs. 1, 2 it is clear that the AC H_2O/LiBr reaches higher EER. Fig.1 shows the reaches higher EER for H_2O/LiBr as NH_3/H_2O at the same temperature in generator. The disadvantage of the working substance H_2O/LiBr is that care should be taken when designing to prevent the crystallization of lithium bromide. The working substance is NH_3/H_2O is used to cool the low temperature below 0°C, because the freezing point of the ammonia is very low (-77.7°C). Although NH_3/H_2O working with lower energy efficient ratio generator operates with higher power (see tab. 2 and fig.2).

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