

The effect of external and operating conditions on a solar Lithium Bromide absorption chiller

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Résumé - La consommation excessive d'énergies fossiles (énergie électrique) pendant l'été causée par le développement technologique implique de plus en plus du réchauffement climatique, afin de faire l'équilibre entre l'offre et la demande d'électricité, en effet la machine à absorption est prometteuse, le principe est de puiser de la chaleur du soleil pour produire du froid. Le cycle de la machine à absorption à simple effet est le cycle le plus simple, il est composé de quatre échangeurs de chaleur utilisant une variété de couples réfrigérants. Le bromure de Lithium eau est le couple le plus utilisé, vu ses multiples avantages, entre autre son coefficient de performance élevé comparé à d'autres couples à des conditions similaires, l'utilisation du couple bromure de Lithium eau fait appel uniquement à un capteur plan pour le chauffage de la solution (couple) dans le générateur. Le but de cette contribution est de quantifier quelques paramètres influents sur l'efficacité de la machine à absorption de puissance de 1 kW.

Abstract – The excessive consumption of fossil energies (electrical energy) during summer caused by the technological development involves more and more climate warming, in order to relieve insistency between electric supply and demand, heat driven absorption chillier is pretty promising, it consists on using heat (solar) as motive energy to provide cold energy. The single effect absorption cycle is the simplest absorption cycle, it's composed of four main components which are all heat exchangers using a diversity couple of refrigerant. Lithium bromide aqueous solution is one of many others solutions widely used in the absorption chiller for cooling purposes; it possesses several advantages over the other type of absorption systems, such as It highest coefficient of performance compared to other absorption units at the same conditions. A simple flat plat collector can assume the energy required for heating the solution in the generator. Even though, LiBr solution may cause the problem of the crystallization and the limitation of this machine on cooling did not affect the economical aspect of LiBr absorption chiller. The main aim of this article is to study the effect of thermal and environmental parameters each compound of an absorption chiller which produce a cool power equal to 1 kW.

Keywords: Solar energy – Cooling – LiBr – Exchanger – Modelling.

1. INTRODUCTION

Vapor absorption refrigeration systems using water-lithium bromide pair are extensively used in large capacity air conditioning systems, they enjoy cooling capacities ranging from kilowatts to megawatts which match with small residential to large scale commercial or even industrial cooling needs.

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LiBr absorption chillers can operate with low regenerating temperature '80 to 110°C', offering the possibility to work with flat plate collectors which are effective and less expensive. Lithium bromide aqueous solution is one of many other solutions widely used in the operation of the absorption heat pumps that are used for cooling purposes. It has been used since the 1950 when the technologies were pioneered by several manufactures in the US.

In these systems water is used as refrigerant and a solution of lithium bromide in water is used as absorbent. The analysis of this system is relatively easy as the vapor generated in the generator is almost pure refrigerant (water), unlike ammonia-water systems where both ammonia and water vapor are generated in the generator.

Several investigations have been conducted:

Txilingiris, presented a microcomputer model to design solar (LiBr-H₂O) absorption cooling system in Greece using about 25 years statistical treatments of meteorological data. Ghaddar *et al.*, modeled and simulated a solar absorption system in Beirut, the cooling power at the evaporator was modeled as a variable load. The results showed that for each ton of refrigeration a minimum area of 23.3 m² of flat plat collector is required.

Best *et al.*, suggested that the main technical problem of cooling systems that are powered by solar energy is that the system is so dependent upon the environment factors such as the temperature of the ambient air and solar radiation,

Schweigler *et al.*, further disclosed an absorption chiller machine in which plate type heat exchangers are used in the absorber and condenser, [1]. Balghouthi *et al.*, accomplished a simulation using TRNSYS program to size the different components of solar absorption. Authors concluded that absorption systems are convenient for Tunisian conditions, [4].

Florides *et al.*, used TRNSYS to model a complete system: absorption machine with solar collectors, storage tank. The results indicated that solar absorption cooling system cannot represent the economical solution, [8]. Sparber *et al.*, reported that till 2007 there were 81 installed large scales solar cooling systems which are currently not in operation, [6]. Assilzadeh *et al.*, designed an evacuated tubular solar collectors and LiBr/H₂O absorption unit. The result showed that a 0.8 m³ hot water storage tank was essential to achieve continuous operation, [7].

2. LI-BR COOLING SYSTEM

The basic single-effect LiBr-water absorption cycle is illustrated in figure 1. The absorber/pump/solution heat exchanger/generator assembly essentially replaces the compressor in a vapor-compression refrigeration system. This assembly is sometimes referred to as a thermal compressor. A dilute (weak) solution of LiBr in water is pumped from the absorber to the generator (1-2). A solution heat exchanger preheats the weak solution before entering the generator (2-3).

A flat Plate collector heats the solution in the generator to boil the water (the refrigerant) from the solution. The water vapor then flows to the condenser (7), where it is condensed and the heat is rejected to the ambience. The condensed water flows through an expansion device (8-9), where the pressure is reduced. The heat flows into the evaporator (9) (providing the desired cooling effect) by evaporating the resulting hot vapor returns to the absorber.

When the water is boiled out of, the remaining solution becomes weak in refrigerant (high concentration of LiBr). The weak solution is cooled in the solution heat exchanger (4-5), and then flows through a flow restriction (5-6) to lower its pressure to return to the absorber. The solution in the absorber absorbs the water vapor returning from the evaporator, diluting the weak solution. Once the solution is reconstituted, it is pumped to the generator (2-3). The entire cycle operates below atmospheric pressure.

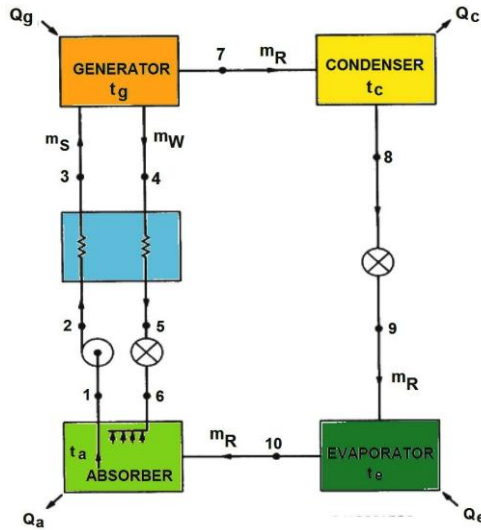


Fig. 1: The basis single effect LiBr water absorption water

3. THERMODYNAMIC STUDY

Some assumptions are considered to set up the heat quantity of the four heat exchanger; condenser, absorber, generator and evaporator.

- There are no pressure changes except through the flow restrictors and the pump.
- In the evaporator, the refrigerant is saturated water vapour.
- Flow restrictors are adiabatic.
- The pump work is negligible.

The thermodynamic properties of each state in the cycle, the amount of heat transfer in each component depend on the following set of inputs:

- | | |
|--|-------|
| • Generator temperature | T_g |
| • Evaporator temperature | T_e |
| • Condenser temperature | T_c |
| • Absorber temperature | T_a |
| • Refrigeration load | Q_e |
| • Liquid-liquid heat exchanger effectiveness | E_1 |

To calculate the different parameters, two methods can be used: using diagrams, or analytical method which is detailed as following [8], both the two give the same results.

The enthalpy of pure water liquid at temperature T is:

$$h_1 = (T - 25) \quad (1)$$

$$h_1 = h_2 \quad (2)$$

The concentration of strong solution is given as:

$$x_1 = x_2 = x_3 = \frac{(49.04 + 1.125 \times T_a - T_e)}{(134.65 + 0.47 \times T_a)} \quad (3)$$

The concentration of the weak solution is given as:

$$x_4 = x_5 = x_6 = \frac{(49.04 + 1.125 \times T_g - T_c)}{(134.65 + 0.47 \times T_g)} \quad (4)$$

According to the assumption 2

$$x_7 = x_8 = x_9 = x_{10} = 0 \quad (5)$$

The refrigerant flow rate is:

$$m_r = \frac{Q_e}{(h_{10} - h_8)} \quad (6)$$

The strong solution flow rate:

$$m_s = m_r \times \frac{x_4}{(x_4 - x_1)} \quad (7)$$

The weak solution flow rate:

$$m_w = m_r \times \frac{x_1}{(x_4 - x_1)} \quad (8)$$

$$t_s = T_g - E_1 \times (T_g - T_a) \quad (9)$$

$$c x_1 = 1.01 - 1.23 \times x_1 + 0.48 \times x_1^2 \quad (10)$$

$$T_8 = T_a + \left(E_1 \times \frac{x_1}{x_4} \times \frac{c x_4}{c x_1} \times (T_g - T_a) \right) \quad (11)$$

$$h_1 = (42.81 - 425.92 \times x_1 + 404.67 \times x_1^2) + (1.01 - 1.23 \times x_1 + 0.48 \times x_1^2) \times T_a \quad (12)$$

$$h_5 = (42.81 - 425.92 \times x_4 + 404.67 \times x_4^2) + (1.01 - 1.23 \times x_4 + 0.48 \times x_4^2) \times T_a \quad (13)$$

The enthalpy of water vapor leaving the generator to the condenser:

$$h_7 = 572.8 - 0.46 \times T_g - 0.043 \times T_c \quad (14)$$

$$h_8 = T_c - 25 \quad (15)$$

$$Q_c = m_R \times (h_7 - h_8) \quad (16)$$

$$Q_g = m_w \times h_5 - m_R \times h_7 - m_s \times h_2 \quad (17)$$

$$Q_a = m_w \times h_6 - m_R \times h_{10} - m_s \times h_1 \quad (18)$$

Experimentally the COP is calculated as the cooling rate produced at the evaporator divided by the heat rate supplied to the generator.

$$COP = Q_e / Q_g \quad (19)$$

4. RESULTS AND DISCUSSIONS

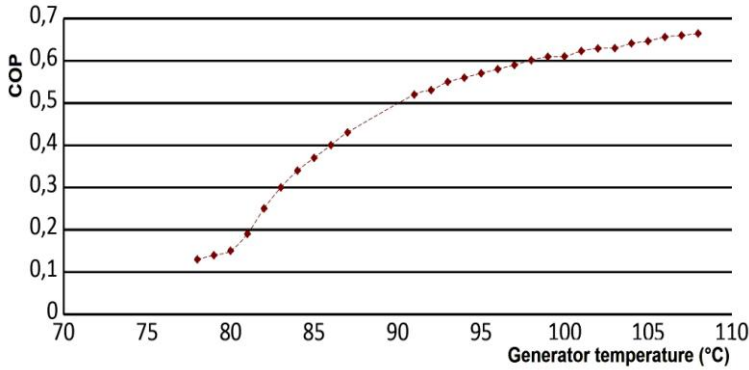


Fig. 2: Effect of the generator temperature on COP

The coefficient of performance COP depends on generator temperature, as shown in the figure 2, more we increase the boiling temperature, the separation of the water vapors occurs easily and consequently we increase the effectiveness of the absorption chiller however the generator inlet temperature could not be increased too much because of the crystallization of the LiBr.

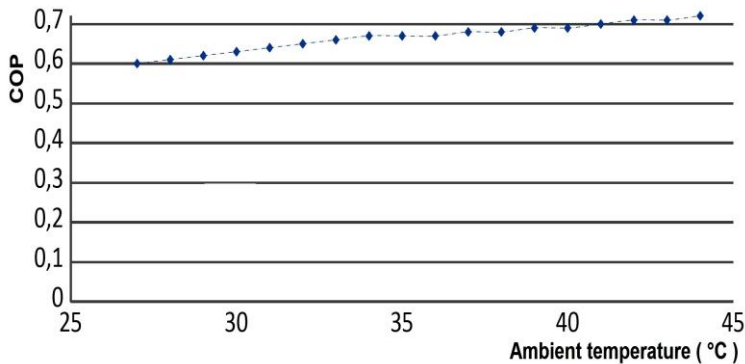


Fig. 3: Effect of ambient temperature on COP

The ambient temperature has a negligible effect on the COP of the chiller, because of the use of water as cooling fluid.

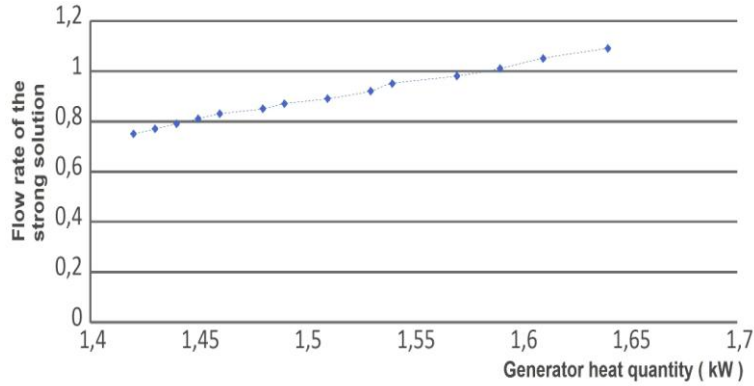


Fig. 4: Effect of the generator heat quantity on flow rate of the strong solution

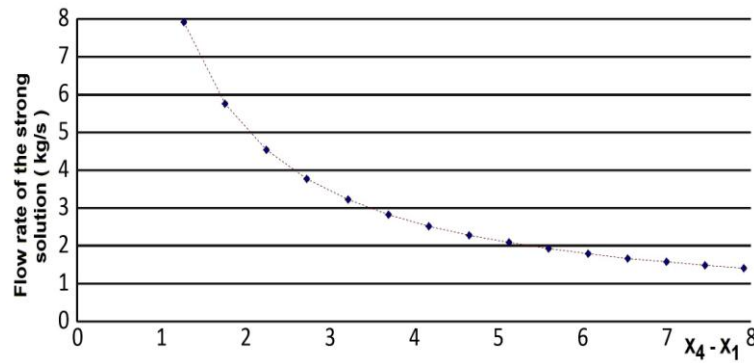


Fig. 5: Effect of the concentration difference between the weak and the strong solution on flow rate of the strong solution

It's noticeable that the concentration differences between the weak and strong solutions in the absorption refrigeration system are strongly related to the mass flow of the refrigerant.

The bigger the concentration difference, the more refrigerant was extracted from the solution.

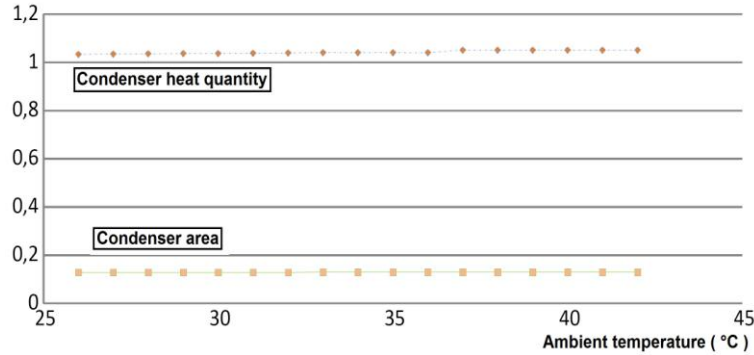


Fig. 6: Effect of the ambient temperature on condenser area and condenser heat quantity

5. CONCLUSION

LiBr/Water absorption chiller is suitable in cooling application; it can operate at low temperature using a simple flat plate collector rather than NH_3/eau which needs a vacuum collector.

According to the exposed results, we conclude that LiBr/water absorption chiller is more convenient than other couple for the same capacity, it doesn't depends on many factors if we use cooling water condenser, air cooling condenser system is affected by ambient temperature which fluctuates along the day.

The generator temperature is an important factor to design an effective absorption chiller, by taking into account the crystallization of the LiBr.

NOMENCLATURE

A : Absorber	C : Condenser
E : evaporator	G : generator
H : Enthalpy	T : Temperature
m_r : Flow rate of the refrigerant	m_s : Flow rate of the strong solution
m_w : Flow rate of the weak solution	Q : Heat quantity
X : Concentration	

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