International Journal Of Advancement In Engineering Technology, Management and Applied Science (IJAETMAS)

ISSN: 2349-3224 || www.ijaetmas.com || Volume 04 - Issue 06 || June-2017 || PP. 62-68

DESIGN OF SOLAR POWERED LITHIUM BROMIDE VAPOUR ABSORPTION REFRIGERATION SYSTEM

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Abstract— *This paper describes the design of a refrigerator using LiBr as working fluid powered by solar energy. The solar energy is stored in DC battery which is then utilized by heating coil and pump. The heat supplied to generator by heat source, heat absorbed by evaporator, heat rejected in condenser to coolant, heat rejected to absorber in coolant is obtained. The maximum COP and Relative COP are obtained from the data. The performance of these three cycles against various generator, evaporator and condenser temperature are compared. The results for LiBr-water show that cycles give better efficiency than ammonia-water cycle.*

Keywords— LiBr, Vapor Absorption Refrigeration System, Enthalpy, Mass Flow Rate, State Points.

I. INTRODUCTION

Solar powered refrigeration system operates without any mechanical or electric power (neglecting pump work) and are independent of electric grids and thus can be used in remote areas to preserve agricultural produce and medicines. Additionally, solar energy is in phase with refrigeration requirements in countries like India.

In order to preserve food temperature below 5℃ is required. For heat powered cooling Ammonia-water refrigeration systems are generally preferred however high input temperature of 90℃ is required. high performance solar collectors are required to supply sufficient solar energy.

Two main categories of refrigeration system are mechanical vapor compression system and vapor absorption refrigeration system. The mechanical vapor compression system is generally preferred because of its higher COP and compactness and ease of manufacture. The biggest problem is a requirement of electricity which generates large amount of carbon di-oxide and CFCs which harm the ozone layer. Due to large power requirements of vapor compression systems and environment impact and consequences solar powered refrigeration systems are preferred as a better option.

Refrigeration is defined as the process of lowering the temperature of an enclosure than surrounding temperature with help of work input. The work input is of mechanical form but can also include heat magnetism electricity laser or other forms. The applications of refrigeration include household refrigerators, industrial freezers and air conditioning. The most important being preservation of food.

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II. WORKING PRINCIPLE

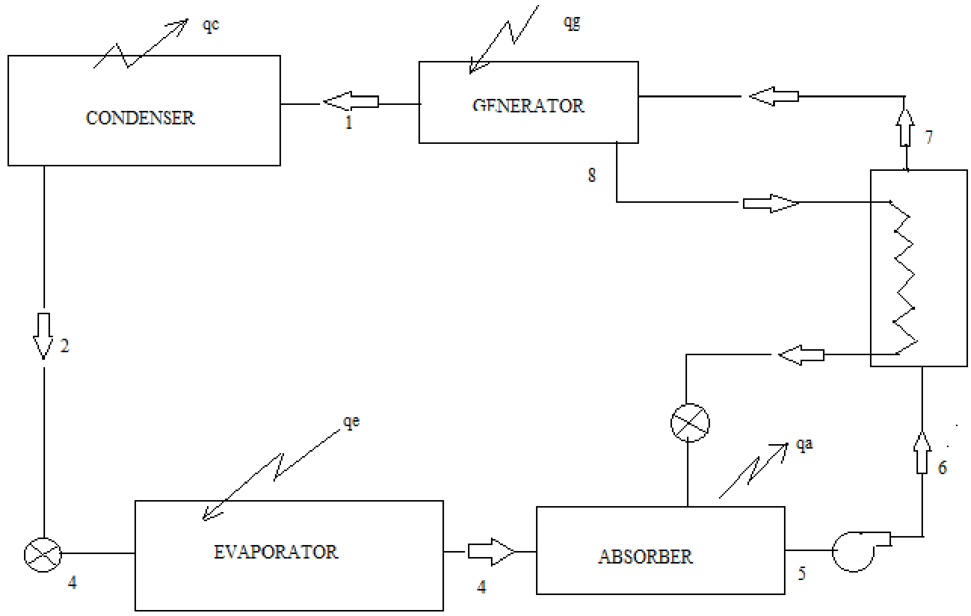

Fig.1 The schematic of the absorption refrigeration cycle.

VARS consists of several components line absorber, generator, condenser and evaporator. The absorber contains binary weak solution of LiBr-water which is pumped to upper tank of generator. The second cycle starts in generator where heating coil of 350 watts which heats the water to a temperature about 100℃ and the water vapor generated is passed to condenser. third cycle is condensate process in the condenser water vapor loses latent heat and is converted to pure water as shown in the figure. The final process is vaporization.

1. Flat plate Solar Collector is used to receive solar energy from sunlight and energy is stored in DC watt.

2. In the generator the solar collector heat is used to separate water from LiBr solution and high temperature and pressure water vapor is generated leaving behind strong solution of LiBr.

3. Then the water vapor passes through the condenser where it is cooled and converted into liquid.

4. This high pressure liquid water is passed to evaporator at low pressure there by

providing cooling.

5. The water vapors enter the absorber.

6. Strong LiBr solution from the generator is sent to the absorber where it absorbs water vapor forming a weak solution.

8. The weak solution is pumped into the generator and the process is repeated.

10. The temperature of the absorber has a high influence on the system efficiency than the condensing temperature.

11. Electricity or conventional boiler can also be used to heat water in the generator.

III. WORKING FLUID FOR ABSORPTION REFRIGERATION SYSTEM

The technology was pioneered in 1950s by several manufacturers in US (Herold et al, 1996) where water acts as refrigerant which absorbs and removes heat from specific environment while LiBr becomes the absorbent that absorbs the water vapor into a solution and makes it possible to be circulated by a solution pump.

As an absorbent LiBr is nonvolatile resulting in cycle designs without rectifiers. Water does not crystallize however the system will work only for temperature above 0℃ due to freezing point of water.

LiBr is a solid lithium salt under normal conditions. It is highly soluble in water and forms a lower equilibrium vapor pressure of solution than pure water at 50℃ 60% LiBr has 6.47 kPa vapor pressure against 12.35 kPa of pure water. This condition is found useful between evaporator and absorber which would dry the refrigerant naturally from the evaporator side to inlet of absorber. Carbon steel and copper are used as construction materials

A fundamental requirement of absorbent refrigeration combination is that in liquid phase they must have margin of miscibility within the operating temperature range of the cycle. The mixture should be chemically stable, non-toxic and non-explosive. The elevation of boiling should be as large as possible. Refrigerant should have high heat of vaporization and high concentration within the absorbent in order to maintain low circulation rate between the generator and absorbent per unit of cooling capacity.

IV. ANALYSIS OF VAPOUR ABSORPTION REFRIGERATION SYSTEM

A. Specifications

Cooling Capacity = 100 ton of refrigeration

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Generator Temperature = 105℃

Condenser Temperature = 45℃

Evaporator Temperature = 5℃

Temperature of solution leaving absorber = 45℃

B. Calculations

The temperatures at 7,8.2 and 4 are known by data. Since 2 and 4 are both saturated states and fluid is pure water ,steam tables are used to get enthalpies and pressure for the saturation temperatures of 45℃ and 5℃.

Also concentration , $c_7 = c_5 = c_6$

Neglecting pump work , $h_5 = h_6$

At point 8 ,saturated liquid $Also\ c_8 = c_9$

At point 9, mass and energy balance are $m_8 = m_4 \left(\frac{c_5 - c_4}{c_8\ c_5}\right)$

But, $m_4 = \frac{Refrigeration\ Load}{h_4 - h_3}$

And $m_5 = m_8 + m_4$

Energy balance for preheater gives,

$$h_9 = h_8 - \frac{m_5}{m_8}(h_7 - h_6)$$

Thus all properties at various points are determined.

For energy balance on generator, we have

$$q_g = m_1 h_1 + m_8 h_8 - m_7 h_7$$

Also for energy balance of condenser

$$q_c = m_2(h_1 - h_2)$$

Also for energy balance on absorber,

$$q_a = m_4 h_4 + m_{10} h_{10} - m_5 h_5$$

Thus heat gained $= q_e + q_g$

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And heat lost $= q_a - q_c$

Thus, heat gained ≈ heat lost

Slight difference is due to value chart reading.

Also COP $= \frac{q_e}{q_g}$

And $COP_{max} = \frac{T_E(T_G - T_O)}{T_G(T_O - T_E)}$

Therefore , $COP_{Relative} = \frac{\text{COP}}{COP_{max}}$

V. RESULTS

The Coefficient of Performance (COP) = 0.76
The Relative Coefficient of Performance ($COP_{Relative}$) = 0.69.

TABLE I
PRESSURE , TEMPERATURE, CONCENTRATION, ENTHALPY, FLOW RATE AT STATE POINTS

State Point	Pressure (mm Hg)	Temp (°C)	Concentration (Kg Lt-Br/kg Mix)	Enthalpy h (kJ/kg mix)	Flow Rate (Mix/ton)
5	6.54	45	0.62	-150	121.173
6	71.87	45	0.62	-150	121.173
7	71.87	95	0.62	-50	121.173
8	71.87	105	0.67	-25	112.13
9	71.87	44	0.67	-133	112.13
10	6.54	-	0.67	-133	112.13
1	71.87	95	0.0	2680	9.0428
2	71.87	45	0.0	188.4	9.0428
3	5	5	0.0	188.4	9.0428
4	5	5	0.0	2510.7	9.0428

The following graphs are obtained for points 1-10 in the system:

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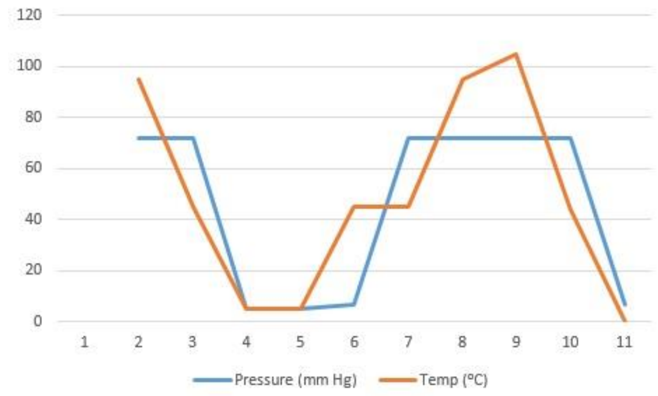

Fig.2: Variation of pressure and temperature in the system

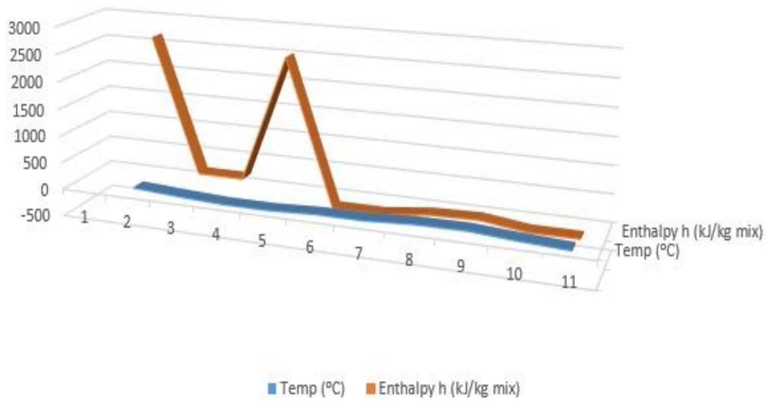

Fig.3: Variation of Enthalpy and Temperature in the system.

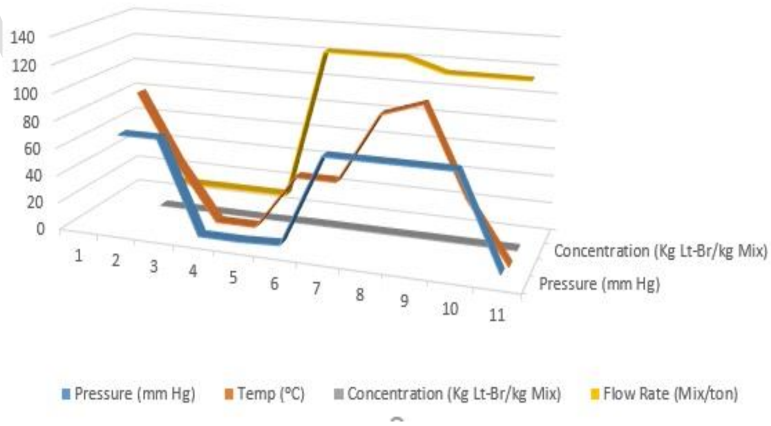

Fig. 4: Variation of Pressure, Temperature, Concentration, Flow rate in the system

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VI. Conclusion

The mass flow rate and thermodynamic properties p, t, h and c are calculated at all points of the system and tabulated in the result table. The COP increases with the increase in generator temperature and vice versa within the respective limits. In the evaporator and generator, the value of exergy increases with increase in their temperature. In the condenser and absorber, the value of exergy decreases with increase in their corresponding temperature. To improve the performance of the system, the absorber should have large mass transfer area and the effectiveness of solution heat exchanger should be high. The temperature of concentrated solution should be always higher than the crystallization temperature. The final design can be optimized using MATLAB simulation for different temperatures.

Acknowledgment

We are thankful to Professor A.P. Kaldate for his support and guidance.

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