Performance Evolution and Modeling of Vapor Absorption System Using Flat Plate Collector

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***Abstract*— This paper presents to evaluate the characteristics and performance of vapour absorption refrigeration system using single stage lithium bromide – water (LiBr – H2O) as absorbent and refrigerant. The all parameters of refrigeration system like evaporator, generator, absorber and condenser for this working fluid described with the help of necessary and appropriate mathematical equation. These equations are analyzed with the help of C language. The generator temperature also required evaluating the performance of refrigeration system, so it must be include in the C language program. These generator temperature values had taken from different cities of Delhi, Bangalore, and Ahmadabad with the help of TRANSYS 16 software.**

I. INTRODUCTION

The refrigeration system is used to chilly articles or substances down to the atmospheric temperature and maintains them at a temperature lower than the ambient temperature. Refrigeration also defines as a process of removal of heat. In our country electricity is the main problem especially in rural areas of state likes Rajasthan, U.P., Bihar etc. electricity is either not available or available for not more than 4 to 5 hrs. Due to the limitation of electricity the refrigeration system is not working properly. So in these conditions or situation it is not possible to preserve or keep the perishable things and drugs safely for long time period which is required cool environment for storage. For this limitation goods are going waste and more importantly due to absence of life saving drugs life span of many livelihoods affected even in some cases many patients' leads to death. Therefore, this paper present is an attempt to design and develop a small solar refrigeration system suitable for rural areas for meeting basic necessities of life. Such solar refrigeration system would be based upon vapor absorption cycle using energy from sun. In most of the rural areas, solar energy is available for free and in abundance. Hence, the system would operate without depending upon grid electricity. Such systems if installed in rural areas would help a great deal in improving the quality of life in rural areas. Besides, in rural areas, such systems can also be used in urban areas for conserving energy.

A. Refrigeration

Refrigeration is a process of lowering the temperature and maintaining it in a given space for the purpose of chilling foods [1], preserving certain substances, or providing an atmosphere conducive to bodily comfort. Storing perishable foods, furs, pharmaceuticals, or other items under refrigeration is commonly known as cold storage. Such refrigeration checks both bacterial growth and adverse chemical reactions that occur in the normal atmosphere.

The science of refrigeration utilizes some of physical property of the matter for producing cold various traditional method of cooling [2] are:

- Ice Refrigeration: This is most traditional method of producing cold and used quiet universally. Ice collected from the surface of ponds and lakes in water was stored in Insulated ice houses for use the year round. For lower temperature salt mixture along with the ice were used.

- Evaporative Refrigeration: This is based on the principle that heat is absorbed when a liquid evaporates. A large part of this heat necessary to cause evaporation comes from the liquid itself. A simple example is the desert water bag used to keep the Drinking water cool at a temperature much below surrounding air temperature.
- Vapour refrigeration: This method works on reversed Carnot cycle and employs vapour of various refrigeration system, as working fluid instead of air. In this vapour refrigeration system heat carried away by the vapour in the refrigerator is in the form of latent heat so the cooling effectiveness is higher than for air refrigeration system working with sensible heat and no change of phase. The necessary components of the system are Compressor, Condenser, Throttling valve and Evaporator.

The conventional refrigeration and space conditional devices are based on vapour compression machines and need electrical energy and/or fossils fuel for their operation. The production of oil and natural gas have become scarcer and their reserves are likely to be consumed by the year 2020 .the production of coal is also not to be promising and its maximum will touch somewhere around 2045 on a word wide basis . With the advent of energy crises and the realization of the depleting nature of the fossils fuel, the search for the use of alternative energy source has become an essentiality .Solar energy has a very high potential amongst renewable sources of energy having no pollution . The power from the sun intercepted by the earth is approximately 1.3×10^{11} MW which is many times larger than the present energy consumption rate on the earth [3].

II. LITERATURE SURVEY

The first generation of solar refrigeration system was built by Mignon and Rouart in 1862 using ammonia-water combination. Since then numerous improvement have taken place in the initial design. Many researchers have developed solar assisted absorption refrigeration systems. Most of them have been produced as experimental units and computer codes were written to simulate systems. Some of these designs are presented here.

In [4], proposed a new combination of LiBr-H2O in place of the ammonia-water combination. The overall COP of the system varied between 0.11 and 0.15 for average evaporator temperature 9 to 13° C. A cooling rate of one tone for every 18 m^2 of collector area was obtained. A solar based refrigeration system developed in [5], a continuous NH3 – H2O absorption system and predicated 37 m2 of collector area required for cooling capacity of 10 kW. This amount of cooling was sufficient to supply energy for space conditioning of a single story house with roof area of 95 m2. typical test result were taken varying the flow rate pressure and temperature in the study state the refrigeration system COP was 0.57 for weak solution concentration of 0.39 and strong solution concentration of 0.58.A novel method reported in [6], the performance of a Brisbane Solar house using H2O – LiBr absorption air conditioner. The solar collection output was amplified using electrically heated water. The condenser and absorber were water cooled. The system also utilized hot water storage and cold water storage facilities. Under transient condition, the COP varied from 0.5 to 0.7 and the room (to be cooled) reached a temperature of 23° C. A cooling rate of 1 Ton was also obtained from 65 m2 of collector area and the overall COP obtained was 0.21.Hammad and Audi (1992) described the performance of non-storage, continuous, solar operated absorption refrigeration cycle in [7]. The maxi- mum ideal coefficient of performance of the system was determined to be equal to 1.6, while the peak actual coefficient of performance was determined to be equal to 0.55.Hawaldar et al. (1993) developed a LiBr absorption cooling system employing an 11×11 m2 collector/regenerator unit in [8]. They also have developed a computer model, which they validated against a real experiment value with good agreement. The experimental result so a regeneration efficiency varying between 38 and 67 % corresponding cooling capacity range 31-72 kW. Ghaddar et al. (1997) presented modeling and simulation of a solar absorption system for Beirut. The results showed that for each ton of refrigeration it is required to have a minimum collector area of 23.3 m^2 with an optimum water storage capacity ranging from 1000 to 1500 l when the system is to operate solely on solar energy for about 7 h per day in [9].

Hammad and Zurigat (1998) described the performance of a 1.5-ton solar cooling unit in [10]. The unit comprises a 14 m2 flat-plate solar collector system and five shell and tube heat exchangers. The unit was tested in April and May in Jordan. The maximum value obtained for actual coefficient- of performance was 0.85. G.A. Florides (2002) present the modeling, simulation and total equivalent warming impact (TEWI) of a domestic-size absorption solar cooling system in [11]. The system consists of a solar collector, storage tank, a boiler and a LiBr–water absorption refrigerator. in the design and costing of an 11 kW cooling capacity solar driven absorption cooling machine which, from simulations, was found to have sufficient capacity to satisfy the cooling needs of a well insulated domestic dwelling. The system is modeled with the TRNSYS simulation program using appropriate equations predicting the performance of the unit. The final optimum system consists of 15 m2 compound parabolic collector tilted at 30° from horizontal and 600 l hot water storage tank. F. Assilzadeha(2005) presents a solar cooling system that has been designed for Malaysia and Similar tropical regions using evacuated tube solar collectors and LiBr absorption unit in [12]. The modeling and simulation of the absorption solar cooling system is carried out with TRNSYS program. The typical metrological year file containing the weather parameters for Malaysia is used to simulate the system. The results presented show that the system is in phase with the weather, i.e. the cooling demand is large during periods that the solar radiation is high. In order to achieve continuous operation and increase the reliability of the system, a 0.8 m3 hot water storage tank is essential. The optimum system for Malaysia's climate for a 3.5 kW (1 refrigeration ton) system consists of 35 m^2 evacuated tubes solar collector sloped at 20°.

III. MODELING OF VAPOR ABSORPTION SYSTEM

This work is based upon the idea of using an existing flat plate collector of solar water heating system that remains idle during the summer months for refrigeration purpose. Here modeling and simulation of such system using LiBr-H2O combination of fluids are presented. The system consists of a typical solar collector integrated with generator, condenser expansion valve, evaporator, absorber and pump as depicted in figure 1.Operating pressure of 9.6 kPa and 1.7 kPa has been considered. Design temperature of evaporator was 150C which is prescribed temperature for preserving several medicines and perishable items. Absorber temperature is 250C equal to average water temperature in this area during summer months. Water flow rate after generator has been kept as 0.35 kg/hr, which was corresponding to limiting condition with given pressure limits to avoid crystallization of LiBr.

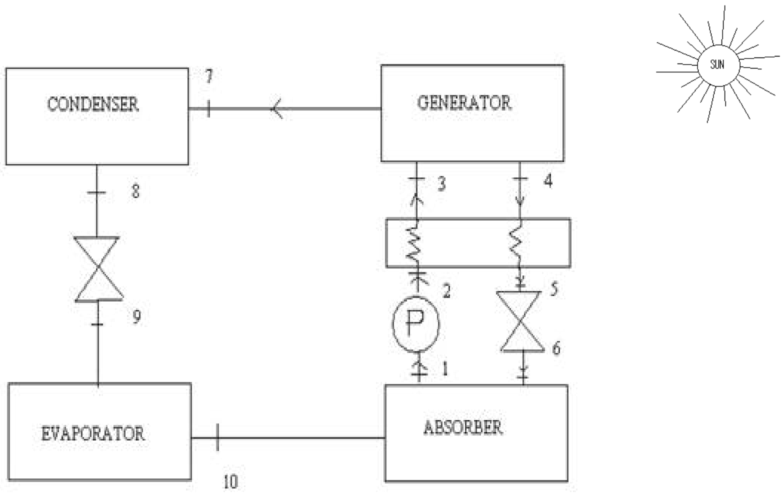

Figure 1. Solar Vapor Absorption Syste

A. Assumptions

- Steady State refrigerant is pure water.
- No pressure change except through the flow resistors and the pump.
- States Point 1, 4, 8 are saturated liquid .
- States Point 10 are saturated vapour .
- Flow resistors are adiabatic .
- Pump is isentropic.

B. Inputs data

- Capacity 3.5 kW
- p1 = 1.7 kPa = 0.017 bar at ts = 15°C
- p2 = 9.6 kPa = 0.096 bar at ts = 45°C
- Generator temperature = 60°C
- Condenser temperature = 45°C
- Evaporator temperature = 15°C
- Absorber temperature = 25°C

C. Evaporator Analysis

In the evaporator the refrigerator is saturated water vapour and the temperature T10 is assumed to be 15°C. The saturation pressure at point 10 is 1.7 kPa (2)

The mass balance on the evaporator is

$$m9 = m10 \quad \ldots\ldots\ldots\ldots \quad \ldots\ldots\ldots (1)$$

The energy balance on the evaporator is

$m9h9 + Qe = m10h10$

$Qe = m10h10 - m9h9$

$Qe = m9\ (h10 - h9)$ …… ………… (2)

Since the evaporative capacity is 3.5 kW. The mass flow rate can be calculated. [Refrigerant H2O flow rate, m7 = m8 = m9 = m10 5.383 kg/hr.

D. Absorber Analysis

Mass balance around the absorber is

$m_{10} + m_6 = m_1$ ……… ……… (3)

LiBr mass balance on absorber

$m_6x_6 = m_1x_1$ …… ………….. (4)

The mass frictions x_6, x_1 are inputs and therefore m_1 and m_6 can be calculated. Finally energy balance on absorber

$Q_a = m_{10}h_{10} + m_6h_6 - m_1h_1$ … …… (5)

Which gives Q_a =5.34 kW

E. Condenser Analysis

Condenser heat can be determined from an energy balance which gives

$Q_c = m_7(h_7 - h_8)$ … …… (6)

And therefore Q_c = 3.626kW

F. Generator Analysis

The heat input to the generator is determined from

$Q_g = m_7h_7 + m_4h_4 - m_3h_3$ … …… (7)

and result in Q_g = 5.47 kW

G. Coefficient of Performance

The C.O.P is defined as

C.O.P = (Q_e/Q_g) … …… (7)

C.O.P is 0.64

The developed algorithm for calculating performance of LiBr-H2O has been coupled with TRNSYS for finding the generator temperature. The system is modeled for typical metrological (15thday of every month) year file containing the weather parameters of Delhi, Ahmedabad, Bangalore and Chennai (Four different climatic zone in India). Initially Heat generated capacity of the system (Qg) is derived from TRNSYS for Flat Plate Collector area of 2m2 having typical BIS specifications. Based upon the generator capacity, further calculations for determined the Evaporator Capacity, Condenser and Absorber Heat rejection specification have been carried

IV. Result & Discussion

Results show that in Delhi, maximum cooling effect of 0.496 kW (0.14ton) can be obtained by using the proposed system. Figure-1 shows variation of evaporator (cooling) capacity with time in all the months at four major cities. The highest evaporative capacity comes in the month of June (Delhi & Ahmadabad) in May (Bangalore) and in March (Chennai). It can be noted that during winters, this capacity reduces by about 48% and during monsoon season by 12 % as compared to peak summer performance.

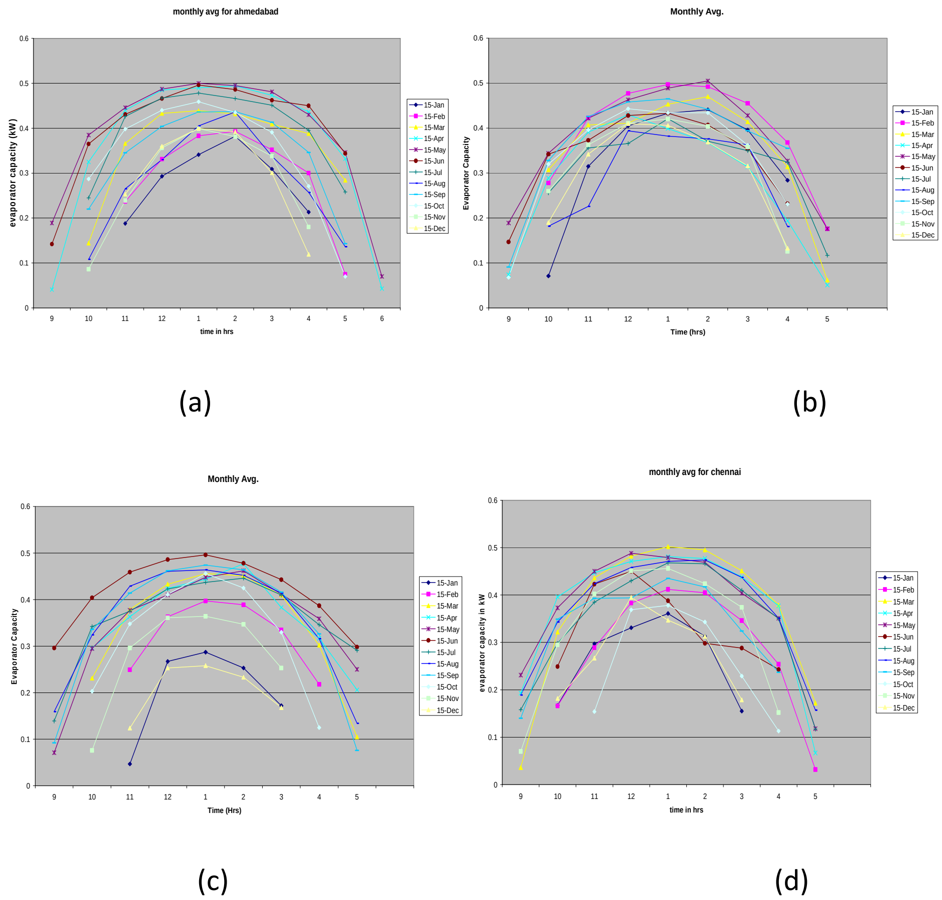

Figure 2. Figure 2 Evaporation Capacity of (a) Ahmadabad (b) Bangalore (c) Delhi (d) Chennai

Figure 2 shows that the highest evaporative capacity occurs in the month of March –June (mostly 11am-4pm of a day) and the lowest evaporative capacity occurs in the month November-January. In the summer season the atmosphere temperature is high in the day time between 11am-4pm at the same time our system gives maximum cooling. Hence this system is very useful for offices, colleges and every other place who's working in day time. Early in the morning, evening and winter season hardly required cooling because the atmospheric temperature is low enough.

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