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Design and Analysis of Solar-Powered Refrigeration System Using Parabolic Collector

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Abstract— Energy consumption increases very rapidly as the world developing. The ever increasing energy consumption world-wide makes it urgent to find new ways to use the energy resources in a more efficient and rational way. Solar energy is currently a subject of great interest, and refrigeration is a particularly attractive .Thus, systems that have the ability to harness solar energy, as the absorption devices, present themselves as interesting alternatives in an intelligent energy management. The objective is to establish a fundamental basis for further research and development within the field of solar cooling. This paper presents simple absorption refrigeration system using Li-Br / H_2O as a working pair. The Li-Br aqueous solution based absorption cycle consists of four stages: generation, condensation, evaporation and absorption with ideally no moving part. The heat input to the absorption system generator is provided by parabolic dish collectors that are coupled to a generator tank. Results and performance of this system and the effects of the refrigeration load inlet temperature on the coefficient of performance, COP of the system are presented.

Keywords— Refrigeration, Absorption System, Lithium-Bromide, Solar Collector

I. INTRODUCTION

Everywhere in the world, refrigeration is a major energy user. In poor areas, “off grid” refrigeration is critically important need. Due to increase in concentration of greenhouse gases and climate changes, the need of renewable energy sources is greater than ever
Both of these consideration point the way towards the refrigeration using renewable energy, as part of a sustainable way of life. . For a refrigeration system that is designed using no energy or minimal amount of energy, absorption refrigeration system is a good solution.

Among various technologies, absorption refrigeration has been most frequently adopted for solar cooling. It requires very low or no electrical input and for the same cooling capacity, the physical dimensions of an absorption refrigeration system are usually smaller than that of an adsorption refrigeration system due to the high heat and mass transfer coefficient of the absorbent. Energy supply to refrigeration and air-conditioning systems constitutes a significant role in the world. The International Institute of Refrigeration (IIR) has estimated that approximately of 15 % electricity produced worldwide is used for refrigeration and air-conditioning. Absorption refrigeration produces air cooling with the use of solar energy, thus electricity has been conserved.

II. SOLAR ABSORPTION REFRIGERATION SYSTEM

Vapour absorption system is one of the oldest methods of producing refrigeration. The idea of vapour absorption system was developed by Michel Faraday in 1824, while performing some set of experiments to liquefy gases. A refrigeration cycle is operated with the condenser, expansion valve, and evaporator if low pressure vapour from the evaporator can be transformed into high-pressure vapour and delivered to the condenser. [3]The vapour compression system uses a compressor for this task.

The absorption system first absorbs the low pressure vapour in an appropriate absorbing liquid.

Embodied in the absorption process is the conversion of vapour into liquid, and since the process is akin to condensation, heat must be rejected during the process.

The next step is to elevate the pressure of the liquid with a pump, and the final step releases the vapour from the absorbing liquid by adding heat.

In a water-lithium bromide vapour absorption refrigeration system, water is used as the refrigerant while lithium bromide (Li Br) is used as the absorbent. In the absorber, the lithium bromide absorbs the water refrigerant, creating a solution of water and lithium bromide. Lithium bromide has great affinity for water vapour, however, when the water-lithium bromide solution is formed, they are not completely soluble with each other under all the operating conditions of the absorption refrigeration system. Because of this, the designer must take care that such conditions would not be created where crystallization and precipitation of the lithium bromide would occur. The capacity of any absorption refrigeration system depends on the ability of the absorbent to absorb the refrigerant, which in turn depends on the concentration of the absorbent. To increase the capacity of the system, the concentration of absorbent

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should be increased, which would enable absorption of more refrigerant. Some of the most common methods used to change the concentration of the absorbent are: controlling the flow of the steam or hot water to the generator, controlling the flow of water used for condensing in the condenser, and re-concentrating the absorbent leaving the generator and entering the absorber.

A. Properties Of Li-Br

TABLE I: PROPERTIES OF LITHIUM BROMIDE

Properties	
Molecular formula	Li-Br
Molar mass	86.845(3) g/mol
Appearance	White solid hygroscopic
Density	3.464 g/cm^3
Melting point	552 °C
Boiling point	1265 °C
Solubility in water	166.7 g/100 mL (30 °C) 254 g/100 mL (90 °C)
Solubility	Soluble in water, methanol, ethanol, ether slightly soluble in pyridine

B. Properties Of Water

TABLE III: PROPERTIES OF WATER

Properties	
Molecular formula	H_2O
Molar mass	18.0152 g/mol
Appearance	White solid, coloureless, transparent
Density	999.9720 Kg/cm^3 for liquid, 917 Kg/cm^3 for gas
Melting point	0 °C
Boiling point	100 °C
Solvent	methanol, acetone

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III. WORKING PRINCIPLE

The main components of absorption system are:
Solar concentrator
Generator
Condenser
Absorber (Storage tank)
Pump

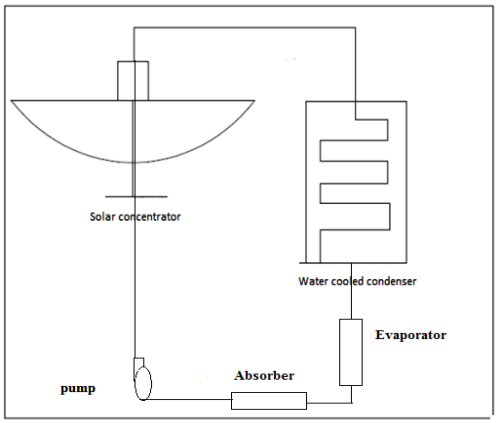


Fig. 1 Layout of Li-Br Absorbtion Refrigeration System

When a solute such as lithium bromide salt is dissolved in a solvent such as water, the boiling point of the solvent (water) is elevated. On the other hand, if the temperature of the solution (solvent + solute) is held constant, then the effect of dissolving the solute is to reduce the vapour pressure of the solvent below that of the saturation pressure of pure solvent at that temperature. If the solute itself has some vapour pressure (i.e., volatile solute) then the total pressure exerted over the solution is the sum total of the partial pressures of solute and solvent. If the solute is non- volatile (e.g. lithium bromide salt) or if the boiling point difference between the solution and solvent is large ($\geq 300^{o}$C), then the total pressure exerted over the solution will be almost equal to the vapour pressure of the solvent only. In the simplest absorption refrigeration system, refrigeration is obtained by connecting two vessels, with one vessel containing pure solvent and the other containing a solution. Since the pressure is almost equal in both the vessels at equilibrium, the temperature of the solution will be higher than that of the pure solvent. This means that if the solution is at ambient temperature, then the pure solvent will be at a temperature lower than the ambient. Hence refrigeration effect is produced at the vessel containing pure solvent due to this temperature difference. The solvent evaporates due to heat transfer from the surroundings, flows to the vessel containing solution and is absorbed by the solution. This process is continued as long as the composition and temperature of the solution are maintained and liquid solvent is available in the container.

Performance of the refrigeration system is represented as a 'coefficient of performance (COP)'. It shows how much heat can be removed from a cold region (Qe) for each unit of energy used (Qg).

$$COP = \frac{Q_e}{Q_g} \qquad (1)$$

IV. EXPERIMENTAL RESULTS

The experimental system used a working fluid combining water as refrigerant and Lithium Bromide as absorbent. The cycle efficiency and operational characteristics of an absorption refrigeration system are dependent on the properties of the refrigerant, the absorbent and their relative mixtures. All the required parameters for the design of a solar powered absorption cooling system were obtained by using calculation techniques for the individual components. Under a working regime, the measured experimental and theoretical values were used to derive the values of COP.

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Fig. 1 Fabricationof Solar Absorbtion Refrigeration System

TABLE IIIII
OBSERVATION TABLE

Sr. No	Time	Solar radiation (W/m^2)	Temp of generator (°C)	Temp of water (°C)	Temp of Surrounding (°C)
1.	11:00	732	35	30	30
2.	11:30	744	46	28	31
3.	12:00	740	52	25	33
4.	12:30	723	59	22	32
5.	01:00	742	66	19	36
6.	01:30	752	71	17	37
7.	02:00	759	78	20	36

A. Analytical Evaluation

This unit evaluation also done on the two basis:
Theoretical
Practical
Estimation of energy supplied and works done.

1) Theoretical : Average radiation = sum of radiations / (no. of observations)

$$= 741.8\ W/m^2$$

$$Cop = \frac{R.E\ (Refrigeration\ effect)}{H.S\ (Heat\ supplyed)}$$

$$R.E = m \times Cp \times \Delta T$$

$$H.S = Solar\ radiation\ ((W/m^2) \times Area\ of\ collector(m^2)$$

$$Cop = \frac{741.8 \times 1.13}{0.017 \times 4.18 \times (27-17)}$$

$$Cop = 0.7482$$

2) Practical: Temperature of generator, $T_g = 78^0C$

Temperature of water , $T_c = 17^0C$

Temperature of surrounding $T_s = 34^0C$

$$\text{Coefficient of Performance, COP} = \frac{(Tg-Ts)}{Tg} \times \frac{Ts}{(Ts-Tc)}$$

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$$Cop = \frac{(78+273)-(34-273)}{(78+273)} \times \frac{(17+273)}{(34+273)-(17+273)}$$

Cop = 0.58

V. CONCLUSIONS

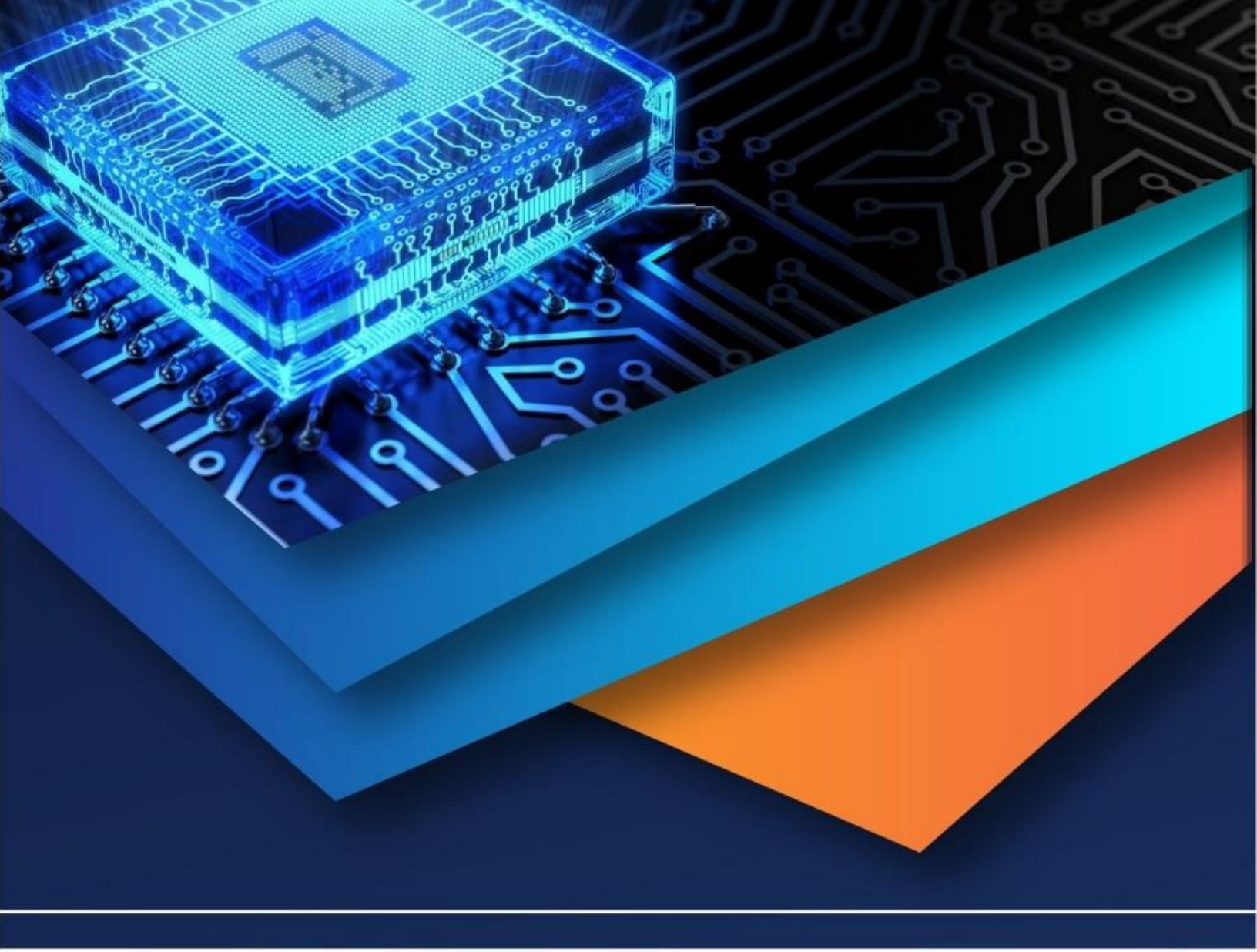
Using Solar Energy as the power source of the system proved to be feasible. Solar Energy being a renewable source of energy proved to be efficient as compared to using electrical energy or steam at the same place. A configuration of a simple LiBr/H2O absorption system is developed in this project. The effects of changing refrigeration load inlet temperature have been investigated and shown. The variation of inlet temperature at constant solutions flow rates and constant external heat supply rate impacts on the performance index of the system and the effectiveness of solution heat exchanger. However, unlimited upward variation of inlet temperature of refrigeration load brings the system near its crystallization point. The implications of this behaviour for real absorption refrigeration system design are clear. With the current results tropical ambient conditions, particularly temperature will boost adoption of absorption refrigeration system. The application of the system would not only ensure comfort for improved productivity at workplaces and homes but could complement strategy to achieve healthy society, job creation and poverty reduction, which are indices for sustainable development. The required capacity of refrigerant is 0.2 Tr .The theoretical COP is 0.74 but we have achieved only 0.58.The pump work and the losses are neglected in this experimental setup.

Lithium bromide and water, with its low price, when used as absorbent and refrigerant pair realize good performance as compared with another types of pairs. Further study for the determination of the economical and optimum solution of water and LiBr is point of analysis work. Efforts following this research will concentrate on using the performance data gathered from the absorption refrigeration test facility to calibrate an absorption refrigeration model for building performance simulation

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