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Design and analysis of solar-powered refrigeration system using parabolic collector

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ABSTRACT

This 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. This report describes 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. Useful information about the of parabolic dish area, generator and absorber tank volume and efficiency of the overall system is presented.

The performance of the system increased with increasing initial temperature of the generator. 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. This project has many possible positive applications from chilled water generation, air conditioning, cooling beverages for sale in remote areas to producing ice for commercial/medical use, with the main goal targeting to achieve the temperature which can be used in different applications.

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

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I. INTRODUCTION

This document is a template. 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.

The particular absorption system of study is one that uses lithium bromide and water as the absorbent and refrigerant, respectively 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.

In a water-lithium bromide vapor 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 vapor, 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 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-

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

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

III. Working Principle

The main components of absorption system are:

- Solar concentrator
- Generator
- Condenser
- Storage tank

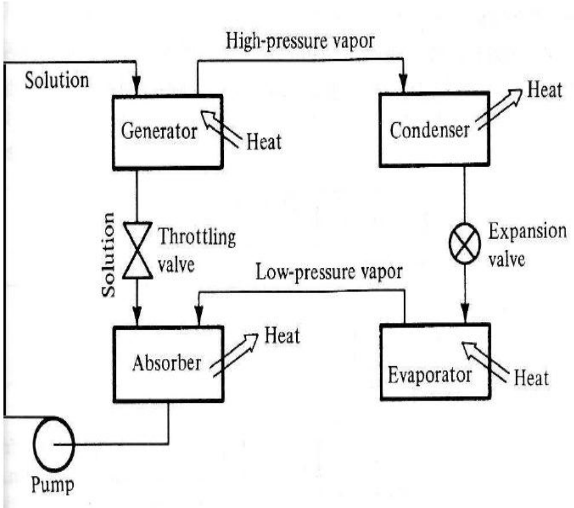

Figure 1. Basic Vapor Absorption System

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 (≥ 300°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).

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

IV. Result And Analysis

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.

Figure 2. Experimental Setup of Li-Br refrigeration System

A. *Theoretical*

Temperature of generator, Tg = 78°C

Temperature of condenser, Tc= 20°C

Temperature of evaporator, Te = -33°C

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

= $\frac{(78+273-20-273)}{(78+273)} \times \frac{(-33+273)}{(20+273+33-2}$

COP = 0.7482

B. *Practical*

Li-Br obtained in storage tank = 138 gms

Quantity of Li-Br = quantity of ice generated

1kg = 1.7 kg o ice at 0°C

$$\frac{1}{1.7} = \frac{0.138}{X}$$

X= 0.2346 kg

Experimental temperature of water = 20° C

Cp = 4.19 KJ/Kg°C m = 0.2346 kg of ice

q = heat absorbed from 20°C - 0°C , cooling effect

q = m*Cp*ΔT

= .2346 * 4.19 * (20-0)

= 19.676 KJ

Energy supplied to the generator = efficiency of the concentrator × time ×average solar radiation × concentrator area

Area of collector = dia. Square × (π/4) = 1.130 sq. m

Average solar radiation = Watts/meter Sq.

= 741.8 W/meter Sq.

Time of experiment = 30 min = 0.5 hours

Energy input = 0.3 × 0.5 × 0.7418 × 1.130 × 3600
= 45.280 KJ

$$COP = \frac{\text{heat removed}}{\text{Heat Supplied}}$$

COP = 0.4345

V. Conclusion

A configuration of a simple LiBr/$H_2$0 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 behavior for real absorption refrigeration system design are clear. With the current results tropical ambient conditions, particularly temperature will boost adoption of absorption refrigeration system.

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References

[1] Syed A., Maged A.I., Muhammad U.,Alternative Designs For A 24-H Operating Solar-Powered Absorption Refrigeration Technology, International Journal Of Refrigeration 35,pp 1967-1977,2012.

[2] Zhaia X., Qu M. , Li Y., Wang R., A Review For Research And New Design Options Of Solar Absorption Cooling Systems, Renewable and Sustainable Energy Reviews 15 ,pp 4416–4423,2011.

[3] Saleh A., Mosa M, Optimization Study Of A Single-Effect Water–Lithium Bromide Absorption Refrigeration System Powered By Flat-Plate Collector In Hot Regions, Energy Conversion and Management 87 ,pp 29–36,2014.

[4] Florides G., Kalogirou S., Tassou S., Wrobel L., Modelling, Simulation And Warming Impact Assessment Of A Domestic-Size Absorption Solar Cooling System, Applied Thermal Engineering 22 ,pp 1313–1325,2002 .

[5] Mazloumi M., Naghashzadegan M.,Javaherdeh K., Simulation Of Solar Lithium Bromide–Water Absorption Cooling System With Parabolic Trough Collector, Energy Conversion and Management 49,pp 2820–2832.2008.

[6] XuaS.,Huang X., Du R, An Investigation Of The Solar Powered Absorption Refrigeration System With Advanced Energy Storage Technology, Solar Energy 85 ,pp 1794–1804,2011.

[7] Kumaresan G., Sridhar R., Velraj R, Performance Studies Of A Solar Parabolic Trough Collector With A Thermal Energy Storage System, Energy 47,pp 395-402,2011.

[8] Cabrera F., Fernandez-Garcıá, Silva R., M. Perez-Garcia, Use Of Parabolic Trough Solar Collectors For Solar Refrigeration And Air-Conditioning Applications, Renewable and Sustainable Energy Reviews 20 ,pp 103–118,2013.

