Experiment Evaluation Of A Solar Two-Stage Absorption System

Mai Bani Younes
Lecturer, Mechanical Engineering, Al-zaytoonah university, Amman, m.baniyounis@zuj.edu.jo.

Abstract: A prime instance of an absorption refrigeration system is a two-stage system, which cools a space in two phases. To attain high efficiency and increased cooling capacity, each stage makes use of a distinct absorber-refrigerant pair. In order to sustain its efficiency, the system efficiently uses the heat that is produced by renewable energy sources. In this work, an experimental evaluation of a two-stage absorption system is carried out. The study was conducted at the site in Aqaba, Jordan, in collaboration with the Jordanian Chamber of Commerce. The system uses solar heaters to heat water, which is then stored in hot water tanks. This hot water is delivered via pipes and pumps to water absorption cooling tanks, where lithium bromide absorbs heat and cools the water. A chiller further cools the chilled water, while a cooling tower dissipates any extra heat. The study focuses on precise temperature control and system adjustments to increase efficiency and compensate for any water loss. Performance evaluation focuses on the coefficient of performance (COP) and cooling capacity. The results show a direct relationship between an increase in the coefficient of performance (COP) and higher temperatures in the absorber, upper generator, and evaporator. At 20 °C absorber temperature, the COP and condenser temperature reach their maximum values of around 1.3 and 32.2 °C, respectively. The maximum COP that can be achieved at different upper generator temperatures is 1.25 at 110 °C. Furthermore, at an evaporator temperature of 8 °C, the cooling capacity reaches 412 kW, and the COP approaches 1.28. These findings are useful for commercial and industrial customers that require efficient cooling, as well as renewable energy advocates, building designers, and regulators interested in supporting sustainable cooling solutions.

Keywords: absorption chiller, refrigeration, two-stage, Solar cooling, LIBR-H2O.

1 Introduction

The temperature in cold storage warehouses affects product quality significantly, but it also increases energy needs, particularly in warm countries [1]. Vapor compression systems, which require electrical power from fuels, are utilized in air conditioning and refrigeration systems. The use of these fuels is harmful for the environment since they emit a lot of CO_2 [2], [3]. It is essential to employ free renewable energy sources (such as wind, geothermal, solar, and others) for air conditioning and refrigeration applications because doing so reduces the need for power and, consequently, the use of fossil fuels [4]. Additional research was done to determine which environmentally friendly refrigerants work best in cycles that employ renewable energy [5]. Pairs driven systems, such as absorption cooling systems with LiBr-H_2O or NH_3-H_2O pairs, are the most commonly utilized [6]. Because the working pressure of absorption cooling systems is typically higher than the outside pressure (ATM), the kind of pair controls this pressure [8]. One efficient method of increasing the pace at which recovered heat is used is to convert waste heat into cooler. Unused heat can be utilized through heat-activated cooling technologies like absorption cooling heat pumps [9]. Numerous technologies exist as experimental prototypes or on the market; their primary differences are in the cooling mixtures that are employed. Water - lithium bromide (H_2O/LiBr) and ammonia water (NH_3/H_2O) are the foundations of the most widely used absorption systems. The primary distinction between these two systems is that, because of its marginally higher performance figure, the lithium bromide mixture-based cycle is typically only appropriate for air conditioning applications, whilst the NH_3/H_2O system is only appropriate for applications below 5°C[10]. The idea of mixing various heating sources with absorption systems has been established by a number of theoretical and practical studies, particularly in recent years [11-15]. The performance coefficient of various LiBrH_2O absorption system designs for Asian climates powered by combined solar and gas energy was investigated by Lubis et al. [11]. They discovered that they could save 60% on energy by using hot (75-90°C) and cold (28-34°C) water, with a COP range of 1.4–3.3. Bellos et al. [12] examined H_2O- LiBr and H_2O-LiCl couples in an absorption system using flat plate collectors. After examining three different ambient temperatures, they discovered that the lithium chloride-water system outperforms the H_2O-LiBr system in every scenario and that its maximum operating temperature is lower. The exergy and energy analysis of a 100kW H_2O-LiBr absorption cycle paired with various collector configurations was recently studied by Bellos et al. [13]. They also reported on the effects of collector temperature on exergetic efficiency, COP, and the running costs of solar absorption systems. Evacuated tube collectors require less room and expenditure than parabolic trough collectors, despite the latter's higher exegetic and energetic efficiency. A simulation for a solar absorption system (single stage lithium bromide-water) using evacuated tube collectors was carried out in Athens, Greece, by Bellos et al. [14]. One of the best favored configurations designs, with a 15-year payback period, is a 450m^2 ETC with a 14 m3 storage tank. They also altered the storage tank size from 6 to 16 m^3, and the ETC's area range is 150 to 600 m^2. Yadav et al.'s [15] simulation of an evacuated tube collector was used to study an absorption cycle. The authors found that the COP ranged from 0.46 to 0.78 for generator temperatures between 54.4°C and 71.1°C. The current research builds upon numerous important studies in the field to add to the expanding body of information on absorption refrigeration systems. In their investigation of double-effect solar absorption cooling systems, Siddique et al. [16] looked at numerous configurations for solar fields as well as hot and cold auxiliary integration strategies. Their research offers insightful information about how to best utilize solar-assisted cooling technology. Similar to this, Ibrahim et al.'s [17] methodical thermodynamic performance evaluation of solar-driven double-effect absorption chillers linked with energy storage demonstrated improvements in solar cooling systems' sustainability and efficiency. In addition, Younes et al. [18] provided both experimental and numerical insights into off-grid applications for rural households by concentrating on the performance evaluation of small-scale ammonia-water absorption systems. Shaban et al. [19] contributed by conducting experimental and statistical analyses of small-scale absorption cycles, specifically assessing the performance of NH3-H2O and LiBr-H2O systems. A thorough mathematical and physical model for a two-stage air-cooled adsorption chiller with heat recovery was created by Makahleh et al. [20], demonstrating the feasibility of such systems under various heat source circumstances. This work supports and expands on these findings by looking into the impacts of temperature optimization on the efficiency of two-stage absorption refrigeration systems, particularly in the context of renewable energy use.

This study tackles the need to improve the efficiency of two-stage absorption refrigeration systems by looking at how different operating parameters affect the coefficient of performance (COP). Despite the system's potential benefits, the ideal circumstances for generating high COP remain unknown. The study intends to undertake an experimental evaluation to identify these situations and select the optimal COP. The study will evaluate the effectiveness of LiBr-H2O systems to other configurations by designing and testing a specific setup. This research is critical for increasing system efficiency and developing sustainable refrigeration systems.

2 System Description

Fig. 1 shows the double effect series flow absorption refrigeration system. The components of the system include two heat exchangers, two solution expansion valves, two refrigerant expansion valves, an absorber, a condenser, an evaporator, a solution pump, a high pressure generator, and a high pressure condenser. Low condensing, high condensing, and evaporating pressures are the three pressure levels. There are three concentration levels for the water-LiBr solution: strong, stronger, and weak solutions. At the absorber outlet, the high generator pressure outlet, and the low generator pressure outlet, respectively, the concentration is weak, strong, and stronger. Only high condenser pressure provides heat to the low generator pressure. Air or hot water/steam are the energy sources that provide heat to the high generator pressure. Water is used to cool the condenser and absorber to aound 24 °C. The evaporator creates chilled water. Heat recovery uses heat exchangers. They improve overall performance by lowering the need for external heat.

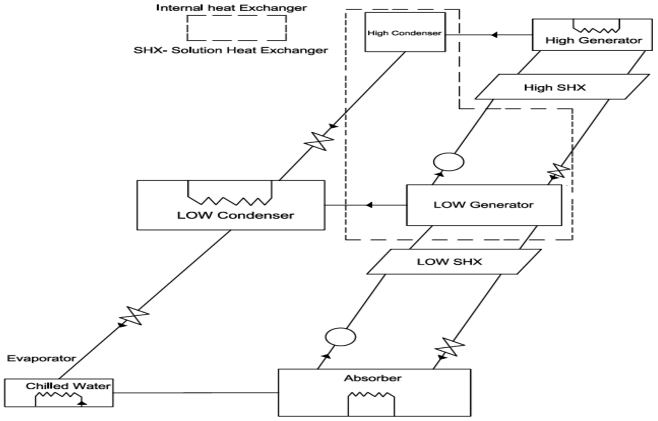

Fig. 1. Illustrative diagram of the operation of two stage Absorption cycle.

Fig.2 illustrates a two-stage absorption cooling system utilizing solar thermal energy for water heating. The system aims to reduce electrical energy consumption and promote the transfer of technology and investment in renewable energy as an alternative source to traditional electricity.

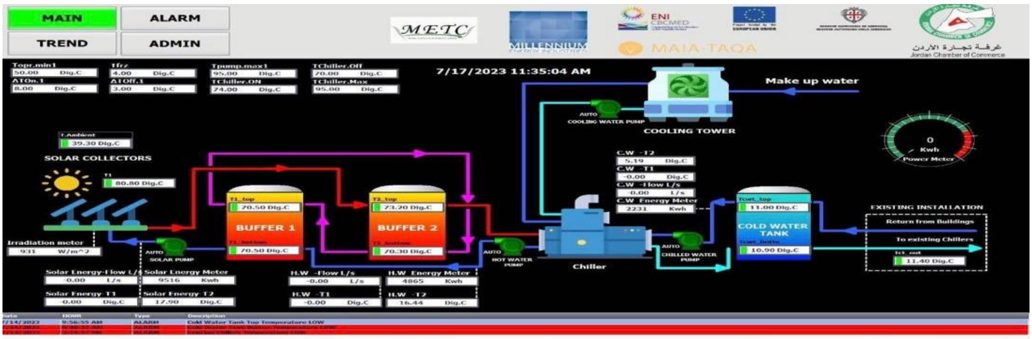

Fig 2. simulation of a two-stage absorption cooling system

The method outlined uses precise temperature control and solar energy in multiple phases to provide effective cooling. Below is a detailed explanation of each step:

- Solar heaters: They heat water by harnessing the sun's energy. Through pipelines, cold water is sent to the solar heaters, where it is heated by the sun's rays.

- Hot water Tanks: The water is kept in hot water tanks for subsequent use once it has been heated by sun heaters.

- Pipes and Pumps: Through the use of pipes and pumps, hot water is delivered from lithium bromide tanks to the water absorption cooling tanks.

- water Absorption Cooling Tanks: This stage uses water absorption cooling technology to cool the hot water. The hot water absorbs heat in these tanks through lithium bromide.

-Chiller: It is used to cool the hot water passing through it from the water absorption cooling tanks. It transfers heat from the hot lithium bromide to the cooling stage.

-Cooling Tower: Used to cool the hot water after passing through the chiller. Excess heat from the hot water is dissipated into the external air.

-System Adjustment and Compensation for Losses: The system is adjusted to ensure high efficiency and large energy savings. Any loss of water in the system is compensated to maintain optimal performance.

-Temperature Control: The system allows users to control the temperature precisely, helping them achieve energy savings and better meet their needs.

Solar thermal heaters are systems that utilize solar energy to heat water or air for residential or commercial use. These systems typically consist of a set of solar panels installed on surfaces exposed to sunlight as shown in Fig.3 , along with pipes or other systems through which fluids absorb heat from the sun and transfer it for use.

Fig. 3. Solar thermal heaters

One of the most crucial components of the system is the chiller as shown in Fig.4, which is connected to the hot water tanks, the cold water tanks, and the cooling tower at its other end. This allows the hot water to pass through the pipes to the chiller, where it starts the process of cooling. The tanks receive cold water from the chiller.

Fig. 4. Absorber Chiller

3 Result and Discussion

The experimental findings and the impact of altering various operating conditions on the performance metrics are covered in this subsection. The operating temperatures of the absorption cycle's constituent parts fluctuate naturally because of the changing climate.

Fig.5 illustrates the effect of changing the absorber temperature on the COP and condenser tempreture, it can be seen that the COP and the condenser tempreture dropped while the absorber tempereture increasing, the COP reaches to 1.07 , while the condenser tempretures approach their minimum values of approximately 29°C at 40°C absorber temperature. By contrast, the COP and condenser temperature approach their maximum values of approximately 1.3 and 32.2°C, respectively, at 20 $^\circ$C absorber temperature.

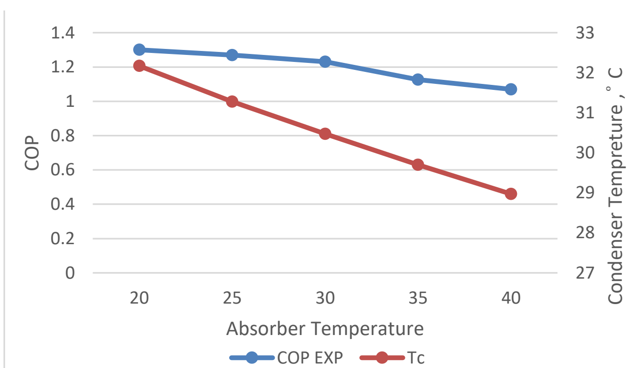

Fig. 5. The Effect of Changing the absorber Temperature on the COP and condenser tempreture

The effect of changing the upper generator temperature on the COP and condenser tempreture can be seen in Fig.6, the figure shows that the COP decreased while the the upper generator temperature increasing. By contrast, the condenser tempreture increases when the upper generator temperature increasing. the maximum COP can be achieved is 1.25 at 110°C upper generator temperature.

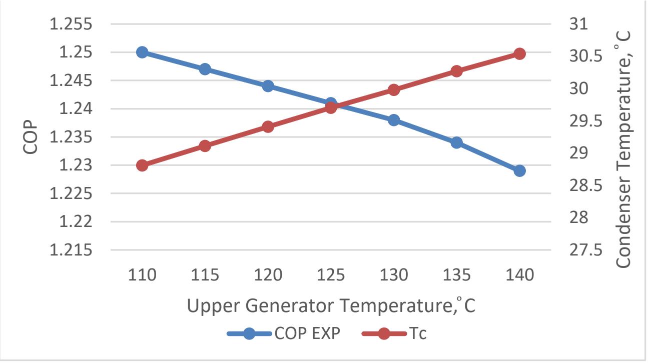

Fig. 6. The Effect of Changing the upper generator Temperature on the COP and condenser tempereture

Fig.7 illustrates the effect of changing the evaporator temperature on the COP and cooling capacity, it can be seen that the COP and cooling capacity increased while the absorber tempereture increasing, the COP reaches to 1.28 , while the cooling capacity reaches to 412 kW at 8˚C evaporator temperature.

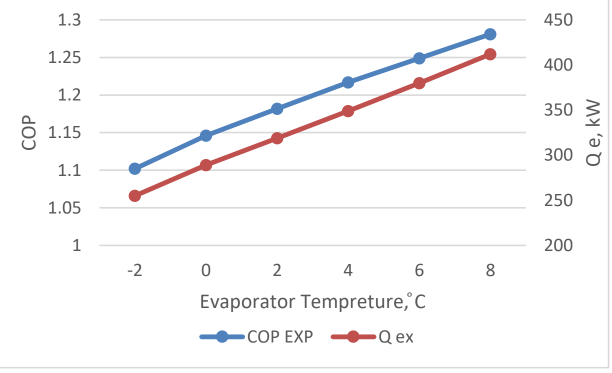

Fig. 7. The Effect of Changing the evaporator temperature on the COP and cooling capacity

These findings shed fresh light on how different operational conditions affect system performance, and they are consistent with previous research demonstrating that temperature tuning might improve efficiency. The findings have practical relevance for designing and running absorption chillers, particularly in adjusting to changing climatic circumstances. The findings, based on experimental data and shown with precise figures, contribute to a deeper understanding of system dynamics and can help drive future advancements in absorption chiller technology.

4 conclusion

Two-stage absorption refrigeration systems, which cool an area in two stages, are a prominent example of this type of system. Each stage uses a different absorber-refrigerant pair to achieve excellent efficiency and enhanced cooling capacity. The system effectively harnesses the heat provided by renewable energy sources to maintain its efficiency. This study evaluates a two-stage absorption system through an experiment. It was carried out in cooperation with the Jordanian Chamber of Commerce in the Aqaba, Jordan, location. Coefficient of performance (COP) and cooling capacity are the main considerations in performance evaluation. The findings demonstrate a clear correlation between rising absorber, upper generator, and evaporator temperatures and an increase in the Coefficient of Performance (COP). The highest values of the condenser temperature and the COP are approximately 32.2℃ and 1.3, respectively, at an absorber temperature of 20℃. At 110℃, the greatest COP that can be attained at various upper generator temperatures is 1.25. Furthermore, the cooling capacity reaches 412 kW and the COP approaches 1.28 at an evaporator temperature of 8℃. The study shows that adjusting temperatures increases the efficiency of two-stage absorption refrigeration systems, allowing for more effective use of renewable energy. However, it is only applicable to Aqaba's conditions and does not address long-term durability or cost analysis. The findings suggest that higher temperatures improve the coefficient of performance (COP) and cooling capacity. These findings are relevant for commercial cooling and renewable energy applications. Future research should focus on different climates, economic impacts, and long-term system reliability.

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Mai Sharaf Aldeen Bani Younes , lecturer of Mechanical Engineering at Al Zaytoonah University of Jordan (10, 2018- present), My academic experiences include Jordan University of Science and Technology, Tolido College in irbid, Jordan, and Al Zaytoonah University of Jordan.
Mechanical machine, power, control systems, energy, renewable energy analysis, thermal systems, and mechanical power system study are among my areas of expertise.