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Review Onn energy Analysis Of Triple Effect Lithium Bromide Absorption Refrigeration System

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Abstract- The decreasing supply of fossil fuels like natural gas, coal, and oil and the growing negative effect of these fuels make renewable energy sources more and more essential. Therefore, absorption refrigeration systems (ARSs) have been increasingly preferred over vapor compression refrigeration systems in recent years. Here are some of ARS primary benefits: They may make use of several renewable energy sources (such geothermal or solar) and, depending on the working fluid pairs employed in the system, do not deplete the ozone layer.therefore, in this paper, a review on energy and exergy analysis of triple effect lithium bromide absorption refrigeration system has been done.

Keywords- Energy, thermal performance, triple effect, absorption refrigeration system

I. INTRODUCTION

Thermodynamic analyses of ARSs and the performance parameters of the cycle have been the subject of several academic investigations. In their extensive literature review on ARS, Karamangil et al. (2010) looked at how different factors, such as operating temperatures (for the generator, evaporator, condenser, and absorber) and working fluid (LiBr-H2O, NH3-H2O, NH3-LiNO2), affected the system's performance indicators (COP and circulation ratio, CR). The study found that compared to RHE and SRHE, SHE has the greatest impact on COP, with a 66% rise in system COP.

Exhaust heat powers a new air-cooled non-adiabatic ejection-absorption refrigeration cycle developed by Li et al. (2017). The thermodynamic analysis of an ARS powered by Diesel engine byproduct heat was conducted by Ouadha and El-Gotni (2013). By altering the temperatures of the cycle's generator, condenser, absorber, and evaporator, a comprehensive thermodynamic analysis of the cycle was carried out over a range of operating situations. They found that the system performed better with greater temperatures in the generator and evaporator and lower temperatures in the condenser and absorber.

thermal exchangers are utilized to recover thermal energy in the ARS, hence Kaynakli and Yamankaradeniz (2003) looked at how this component of the system affected the COP. Based on the results of this research, it has been determined that the solution heat exchanger (SHE) is the optimal heat exchanger for the system. The study of Abed et al. (2015) centered on improving the efficiency with which the ejector-flash tank-ARS utilised NH3-H2O for heat recovery. Incorporating RHE into the planned cycle resulted in a 4.85% increase in refrigeration capacity. Sencan (2007) evaluated the efficiency of NH3-H2O ARS using a neural network model. To reduce the temperature of the intake air in an internal combustion engine utilizing the engine's exhaust gas as a heat source, Novella et al. (2017) did a thermodynamic study of an absorption refrigeration cycle. In general, this research studied the system's effects on the COP and looked at the many aspects impacting the ARS's first law efficiency.

Bademlioglu et al. (2018) used Taguchi and ANOVA to investigate the effect of parameter weights on ORC's first-law efficiency. Evaporator temperature, condenser temperature, and turbine isentropic efficiency were shown to have the greatest impact on the ORC's thermal efficiency, with a combined effect ratio of 70% being computed for the study's parameters. Taguchi analysis was used by Coskun et al. (2012) to find the important parameters and optimal operating conditions for a waste heat recovery application. Arslanoglu and Yigit (2017) used the Taguchi technique to rank the significance of several characteristics on the optimal insulating thickness. Furthermore, ANOVA was used to calculate the influence ratio of each parameter.

However, comprehensive research that takes a statistical approach to assessing all these characteristics and estimating their contribution ratios on the system's performance has yet to be found in the literature. This study aims to identify which parameters have the most impact on the ARS's COP values and rank them according to their significance using Taguchi techniques. Furthermore, several statistical analysis techniques are utilized to ascertain the best and worst working circumstances and then compare the outcomes.

II. VAPORABSORPTION REFRIGERATION SYSTEM

A Vapor Absorption Refrigeration System (VARS) is a type of refrigeration system that cools or refrigerates a space or substance by absorbing and desorbing a refrigerant within an absorbent medium, rather than using a mechanical compressor as in traditional Vapor Compression Refrigeration Systems (VCRS). In a Vapor Absorption Refrigeration System, heat is used as the primary energy source to drive the refrigeration cycle. These systems are known for their energy efficiency and are particularly well-suited for certain applications and environments[9].

Working of Simple Absorption System

A Simple Absorption System is a type of refrigeration system that uses the principle of absorption to provide cooling. Unlike vapor compression systems, which use mechanical compressors, absorption systems use heat as their primary energy source to generate cooling. Here, we'll outline the basic working principles of a simple absorption system:

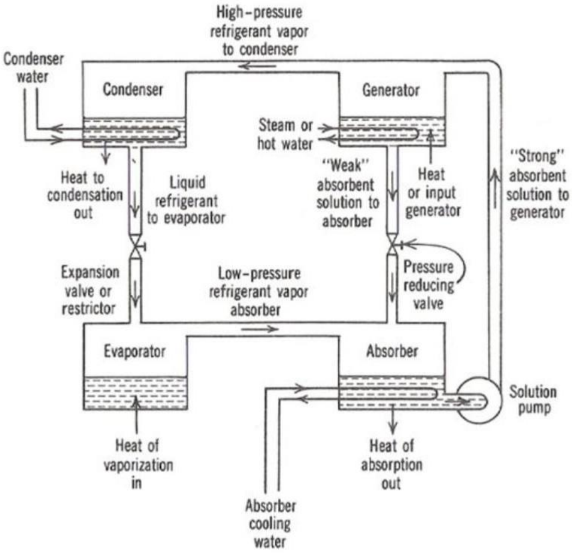

Fig1 Basic Absorption Refrigeration Cycle

2.Components of a Simple Absorption System:

Absorber: This is where the refrigerant vapor is absorbed into an absorbent solution. It operates at a relatively low temperature. Generator (or Evaporator): The generator is responsible for desorbing (evaporating) the refrigerant from the absorbent solution. It operates at a higher temperature and is heated using an external heat source.

Condenser: In the condenser, the refrigerant vapor from the generator is condensed into a liquid state, releasing heat to the surroundings.

Evaporator: The evaporator is where the liquid refrigerant from the condenser evaporates, absorbing heat from its surroundings (e.g., the air or fluid to be cooled). This process provides the cooling effect.

Solution Pump: A solution pump circulates the absorbent solution between the absorber and the generator, maintaining the continuous cycle.

Working of a Simple Absorption System:

1. Absorption (Absorber): The cycle begins in the absorber, where a dilute absorbent solution (often a mixture of water and lithium bromide) comes into contact with the refrigerant vapor (usually water). The refrigerant vapor has been previously vaporized in the evaporator and is now seeking to be absorbed into the absorbent solution. Due to the strong affinity between the refrigerant and the absorbent, the refrigerant vapor is absorbed into the solution, creating a dilute solution.
2. Pumping (Solution Pump): The dilute solution from the absorber is pumped into the generator.
3. Desorption (Generator): In the generator, the dilute absorbent solution is heated using an external heat source, such as natural gas or steam. The heat causes the refrigerant to desorb or vaporize from the solution. The refrigerant vapor, now in its gaseous state, rises and leaves the generator.
4. Condensation (Condenser): The refrigerant vapor from the generator is directed to the condenser, where it releases heat to the surroundings and condenses into a liquid. This heat release is typically transferred to the environment or a cooling medium.
5. Evaporation (Evaporator): The condensed liquid refrigerant from the condenser enters the evaporator, where it evaporates, absorbing heat from its surroundings. This absorption of heat results in a cooling effect, which can be used to maintain low temperatures in the space or substance to be cooled.
6. Return to Absorber: The refrigerant vapor from the evaporator returns to the absorber, where it re-enters the absorbent solution. The cycle repeats as the refrigerant is absorbed again, and the solution is pumped back to the generator for desorption.

The key principle behind a simple absorption system is the use of heat to drive the absorption and desorption of the refrigerant in the absorbent solution, creating a continuous cycle that provides cooling. This type of system is often used in applications where waste heat or low-grade heat sources are available for cooling purposes, making it an energy-efficient and environmentally friendly choice.

Practical Absorption Refrigeration Cycle

The practical absorption refrigeration cycle is a thermodynamic process used in absorption refrigeration systems to provide cooling or refrigeration by absorbing and desorbing a refrigerant within an absorbent solution. Unlike vapor compression refrigeration, which relies on a mechanical compressor, absorption refrigeration uses heat to drive the cooling cycle. Here's a description of the practical absorption refrigeration cycle:

Components of a Practical Absorption Refrigeration System:

Generator (G): This component is responsible for desorbing the refrigerant from the absorbent solution. It is heated using an external heat source, which can be steam, hot water, or other heat sources, depending on the application.

- Absorber (A): The absorber receives the vaporized refrigerant from the generator. In this component, the refrigerant vapor is absorbed into the absorbent solution, creating a concentrated solution.
- Condenser (C): The condensed refrigerant vapor from the absorber is sent to the condenser, where it releases heat to the surroundings and turns into a liquid state.
- Evaporator (E): In the evaporator, the liquid refrigerant from the condenser evaporates, absorbing heat from its surroundings (e.g., the air or fluid to be cooled). This process creates the cooling effect.
- Solution Pump (P): The solution pump is responsible for circulating the absorbent solution between the absorber and the generator, maintaining the continuous cycle.

Working of the Practical Absorption Refrigeration Cycle:

- Absorption (Absorber): The cycle begins with the absorber. In this stage, the absorbent solution, which has previously absorbed refrigerant in the generator, is in a concentrated state. The vaporized refrigerant, usually ammonia (NH3), but can vary depending on the system, enters the absorber. The strong affinity between the refrigerant and the absorbent causes the refrigerant vapor to be absorbed into the solution, creating a dilute solution.
- Pumping (Solution Pump): The dilute solution from the absorber is pumped into the generator.
- Desorption (Generator): In the generator, the dilute absorbent solution is heated, often by an external heat source. This heat causes the refrigerant to desorb or vaporize from the solution. The refrigerant vapor, now in its gaseous state, rises and leaves the generator.
- Condensation (Condenser): The refrigerant vapor from the generator is directed to the condenser, where it releases heat and condenses into a liquid. This heat release is typically transferred to the surroundings or dissipated through a cooling medium.
- Evaporation (Evaporator): The condensed liquid refrigerant from the condenser enters the evaporator, where it evaporates. During this phase change, the refrigerant absorbs heat from the surroundings (e.g., the air or fluid being cooled), creating a cooling effect.
- Return to Absorber: The refrigerant vapor from the evaporator returns to the absorber, where it re-enters the absorbent solution. The cycle repeats as the refrigerant is absorbed again and the solution is pumped back to the generator for desorption.

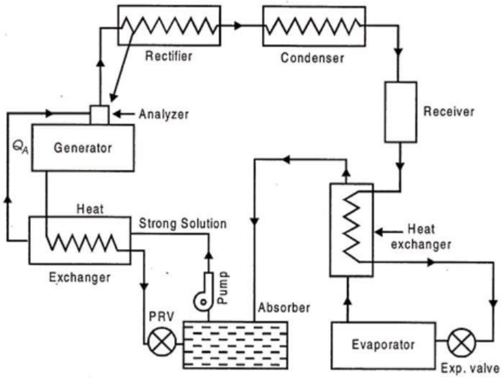

Fig 2 Practical Absorption Refrigeration Cycle

III.TRPPL EEFFECT APOUR ABSORBTION SYSTEM

A Triple Effect Vapor Absorption System is a highly efficient variation of an absorption cooling system used for air conditioning, refrigeration, and other cooling applications. It utilizes the principle of multiple absorption cycles to achieve greater energy efficiency compared to single or double-effect systems. In a triple effect system, there are three distinct absorption cycles or stages, each with its own generator, absorber, and condenser. Here's a detailed description of the working principle of a Triple Effect Vapor Absorption System, along with a simplified figure:

First Effect (High-Temperature Stage):

- In the first effect, a high-temperature heat source (usually steam or hot water) is used to heat a solution of a strong absorbent (typically lithium bromide - LiBr) in the generator. The high temperature causes the refrigerant (usually water) to evaporate from a concentrated solution of the absorbent.
- The vaporized refrigerant, now in its gaseous state, is drawn off from the first generator and directed to the first condenser, where it is condensed into a liquid using a cooling medium, often water.
- The condensed refrigerant is then collected and sent to the first evaporator, where it evaporates, absorbing heat from the surroundings and creating a cooling effect.

Second Effect (Intermediate-Temperature Stage):

- The partially spent absorbent from the first effect (i.e., the absorbent with a lower concentration of refrigerant) is transferred to the second generator, where it is further heated, but at a lower temperature compared to the first generator.
- This lower temperature causes the remaining refrigerant to evaporate from the absorbent solution in the second generator.
- The vaporized refrigerant from the second generator is then condensed in the second condenser, releasing heat.
- The liquid refrigerant is collected and directed to the

second evaporator, where it evaporates, absorbing more heat from the surroundings and producing additional cooling.

Third Effect (Low-Temperature Stage):

- The absorbent solution, now with a very low concentration of refrigerant, is transferred to the third generator, which operates at an even lower temperature.
- In the third generator, the remaining refrigerant is evaporated from the solution.
- The vaporized refrigerant from the third generator is condensed in the third condenser, releasing more heat.
- The liquid refrigerant is collected and sent to the third evaporator, where it evaporates, absorbing additional heat and providing the final cooling effect.

Overall Operation

- In a Triple Effect Vapor Absorption System, each effect operates at successively lower temperatures. As a result, the system utilizes heat more efficiently, making it highly energy-efficient and suitable for applications where waste heat or low-grade heat sources are available.
- The heat source for each effect can be provided by various means, such as steam, hot water, or even solar energy, depending on the application and availability of heat sources.
- The three cooling effects from the evaporators can be used for different purposes or distributed to various cooling loads, enhancing the system's versatility and efficiency.

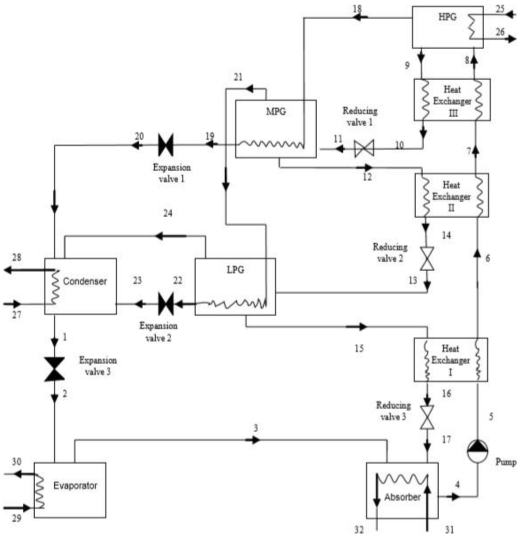

Fig 3 Working principle of triple effect absorption refrigeration system

Refrigerant-Absorbent combinations for Vapor Absorption Cooling Systems

Vapor absorption cooling systems offer an energy-efficient and environmentally friendly alternative to traditional vapor compression cooling systems. Central to the functioning of these systems are the refrigerant-absorbent combinations, which are carefully selected to achieve optimal cooling performance while minimizing environmental impact.In vapor absorption cooling systems, the refrigerant-absorbent pair forms the heart of the thermodynamic cycle. This pair consists of a refrigerant that undergoes evaporation and condensation, providing the cooling effect, and an absorbent that facilitates the absorption and desorption of the refrigerant. The choice of this combination greatly influences the system's efficiency, environmental impact, and suitability for various applications.

Properties of Ideal Refrigerant-Absorbent Combinations

- High Affinity for Absorption and Desorption: The refrigerant should readily absorb into the absorbent in the absorber when exposed to the right conditions. Similarly, during desorption in the generator, it should separate easily from the absorbent when heated.
- Large Heat of Absorption and Desorption: A significant heat of absorption (heat released during absorption) and heat of desorption (heat absorbed during desorption) contribute to the overall efficiency of the system. These properties determine the cooling capacity of the system.
- Chemical Stability: Refrigerant-absorbent mixtures must be chemically stable to prevent corrosion or degradation of system components. This stability ensures the longevity and reliability of the cooling system.
- Low Vapor Pressure of Refrigerant: Refrigerants with low vapor pressure at the desired operating temperatures help maintain pressure conditions within the system, reducing the risk of leakage and ensuring safety.
- Thermodynamic Compatibility: Compatible thermodynamic properties, such as vapor pressure-temperature relationships and solubility characteristics, are essential for stable and efficient cycle operation.

Selection Criteria for Refrigerant-Absorbent Pairs

The choice of a refrigerant-absorbent pair depends on several factors, including:

- Operating Temperature Range: The mixture should be suitable for the desired cooling temperatures, whether low, moderate, or high.
- Efficiency: The pair should provide efficient cooling while minimizing energy consumption. High heat of absorption and desorption contribute to improved efficiency.
- Environmental Impact: Environmentally friendly pairs have low global warming potential (GWP) and zero or low ozone depletion potential (ODP), reducing their impact on climate change and ozone layer depletion.
- Safety: Non-toxic and non-flammable mixtures are crucial for operator and environmental safety.
- Cost and Availability: The cost and availability of refrigerants and absorbents should be considered to ensure affordability and accessibility.
- Application Suitability: The chosen pair must align with

the specific requirements and constraints of the application, whether it's air conditioning, industrial cooling, or refrigeration.

Impact on Sustainability

Refrigerant-absorbent combinations play a vital role in the sustainability of vapor absorption cooling systems:

- Energy Efficiency: The right pair enhances the system's energy efficiency, reducing energy consumption and greenhouse gas emissions. This is particularly important in the context of climate change mitigation.
- Environmental Friendliness: Environmentally friendly pairs, with low GWP and ODP, align with sustainability goals and contribute to a greener future.
- Resource Conservation: By optimizing cooling processes, these combinations reduce the consumption of natural resources, such as electricity and water.
- Longevity and Reliability: Stable and chemically compatible pairs contribute to longer system lifetimes, reducing the need for frequent replacements and waste generation.

Refrigerant-absorbent combinations are the backbone of vapor absorption cooling systems. Their careful selection, based on properties and application requirements, influences system efficiency, environmental impact, and long-term sustainability. As the world seeks more eco-friendly and energy-efficient cooling solutions, the significance of these combinations cannot be overstated. With ongoing research and technological advancements, the future of vapor absorption cooling systems holds the promise of even more efficient and sustainable refrigerant-absorbent pairs, contributing to a cooler and greener planet.

IV.PASTSTUDIES

Mohtaram andWeidong, (2023)Employing an Ejector Expansion Transcritical CO2 (EETC) cycle and a single effect lithium bromide water Vapour Absorption Refrigeration System (VARS), this paper investigates the energy and exergy efficiency of a hybrid refrigeration system. The absorption refrigeration cycle begins with the release of heat, which is accomplished by the EETC cycle compressor producing high-temperature carbon dioxide. Fundamental concepts for understanding the behavior of energy in a thermodynamic system, the first and second thermodynamic laws, were used to a thorough evaluation and analysis of the system.

Aktemur and Ozturk (2023)Absorption chillers, which use almost little power, have become increasingly popular in the past few decades for use in HVAC systems. Absorption chillers provide for huge energy savings, especially in Turkey due to the country's abundance of solar energy and other renewable energy sources. Comprehensive energy and exergy studies of a LiBr + LiCl/H2O (mass ratio 2:1) solution solar-driven single-effect absorption chiller are presented in this paper.

Sharma and Ali (2023)When designing a solar-powered, single-effect LiBr-H_2O vapour absorption system with latent heat thermal energy storage, the choice of PCM is crucial. For a solar-powered LiBr-H_2O vapour absorption system to function, PCM has to have a melting point in the range of 80 to 100°C and a high latent heat of fusion. Initially, melting temperatures between 80 and 100 degrees Celsius are used to evaluate a total of 14 PCMs. The MADM test is also used to rate them and to confirm their placement. As well as price, the thermophysical characteristics of PCM (such as latent heat, density, thermal conductivity, and specific heat) were taken into account throughout the selection procedure.

Liu and Zhang, X. (2023)Low-pressure compression-assisted absorption refrigeration systems (LCARS) that utilise two unique low-GWP HFC-based binary working pairs may be able to solve the problems plaguing conventional absorption refrigeration systems. To investigate the experimental performances of both pairings, an experimental prototype with a cooling capacity of up to around 2 kW and the ability to function as LCARS and single-stage absorption refrigeration system (SSARS) was developed. In SSARS, the highest cooling capacity of the R161-based mixture is 1.012 kW, whereas the maximum cooling capacity of the R152a-based mixture is only 2.316 kW.

Ibrahim et al. (2023)In order to expand the cooling capacity of powered by sunlight systems, it is common practice to store heat in the form of hot water. High thermal losses are the primary drawback of sensible heat storage. The performance of a double-effect absorption chiller is superior to that of a single-effect type while running in the common generating temperature range of 150°C to 180°C. Absorption energy storage (AES) is recommended for use with a double-effect chiller powered by parabolic trough solar collectors due to the high working temperature range of the chiller in this study. Since AES uses chemical potential to store heat, the problem of heat loss is greatly reduced. Taking into account the unfavorable solution crystallization phenomena under a range of operational situations, this work proposes a model of the integrated system and its performance evaluation. Findings show there is a significant risk of solution crystallization in the chiller during the charging operation when the solution distribution ratio is less than 50%.

Li et al. (2023)In this paper, we propose a low-temperature working pair of lithium bromide (LiBr)+1-butyl-3-methylimidazolium bromide ([BMIM]Br)/ethanol (C2H5OH) for a double-effect absorption refrigeration system that can operate at temperatures well below zero and reduce the driving heat source temperature. The thermodynamic performance of the double-effect absorption refrigeration cycle was estimated in Matlab for a range of operating circumstances using the observed thermal characteristics, and results were compared to those obtained using a LiBr/H_2O working pair. "Under the same operating conditions, the results revealed that the refrigeration system's generation temperature could be lowered by roughly 30 K by replacing LiBr/H_2O with LiBr-[BMIM]Br/C_2H_5OH.

V. LITERATURE REVIEW SUMMARY

A. The absorption-compression cascade cycle, which utilizes both heat and electricity, presents several advantages over VAR (Vapor Absorption Refrigeration) and VCR (Vapor Compression Refrigeration) cycles, each with its own set of merits and drawbacks. The extensive body of literature on cascade refrigeration systems, sourced from reputable databases like Scopus, ScienceDirect, ResearchGate, Google Open Access, and others, contributes valuable insights into these systems. These research efforts encompass energy and exergy analyses of VCR cycles, single, double, and triple-stage VAR cycles, as well as combined or cascade cycles that integrate compression and absorption technologies. Historically, the focus has been predominantly on mixed compression-absorption or cascade cycles, along with single and double-stage VCR and VAR cycles. While there has been considerable research into cascade cycles, limited attention has been directed toward evaluating the thermodynamic performance of the triple-effect VAR cycle. Additionally, there is a noticeable dearth of literature that comprehensively analyzes the efficiency of a series flow cascade refrigeration system incorporating compression, absorption, and adsorption processes.

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