Numerical Analysis of Absorption refrigeration system using different Refrigerants with various heat sources.

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DEDICATION

All of our diligences are dedicated to the visionary Philosophy and poetic eloquence of Allama Iqbal, and to our Parents whose sacrifices and encouragement have been a guiding light throughout this academic journey.

ABSTRACT

This Project is titled **"Numerical Analysis of Absorption Refrigeration system Using different refrigerant with various heat source"** is basically involved in the theoretical study of absorption refrigeration system with highest working efficiency and optimum environmental impact. This system is driven by various heat sources with different pairs of solutions in the generator. Data for perimeters of absorption refrigeration system is taken from three key references. First key reference proposed a comprehensive structure of Absorption refrigeration system which is driven by waste heat gases of a diesel engine. Exhaust temperature is calculated as 110°C, The Generator temperature set at 90°C and cooling load produced is 50W with 0.42 COP of system. 2nd reference proposed an analytical structural model for solar powered absorption refrigeration system. Libr-Water solution in generator heated up by solar collector at 65°C. Cooling load at evaporator set at 5.2kW and COP of system is 0.87. 3rd key reference is taken by a fellow group whom calculated thermal losses in a steam power plant of **DG CEMENT POWER PLANT SAEEDABAD GODOWN.** Exhaust flue gases are flowing out through chimney at 140°C. These high temperature exhaust flue gases are taken as 3rd heat source at generator of system. There are Two further methods adopted for numerical analysis i.e. Analytical method and Qualitative analysis method. To calculate heat transfer rate and mass flow rate at each stage of absorption refrigeration cycle, a mathematical model based on law of conservation of mass and law of conservation of energy is derived. By analysis we conclude, 2nd key reference proposed Lithium Bromide-Water (LiBr-H_2O) Vapor Absorption Refrigeration System Based on Solar Energy with highest efficiency of 0.87 and optimum environmental effects. This is the best absorption refrigeration system achieved in this research for producing cooling load.

BALOCHISTAN UNIVERSITY OF ENGINEERING ANDTECHNOLOGY

KHUZDAR

Certificate

Department Of Mechanical Engineering

This is certify that the work present in the thesis on **" Numerical Analysis of Absorption Refrigeration system Using different refrigerant with various heat source "** is entirely written by the following students underthe supervision of Asst. Prof. Javid Iqbal The results obtained by us have not been submitted to any other university or institute, either in part or in full, for the award of any other degree.

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Chapter NO: 1

Introduction

1.1. Background

The concept of absorption refrigeration system is not a recent invention, its roots can be tracked back to the 18^{th} century **[21]** The basic principle of absorption refrigeration system was first discovered by Micheal Faraday in 1824. He performed a set of experiments to liquefy certain gases. Edmond Carré developed the first absorption machine in 1850, using water and sulfuric acid **[21]**. His brother, Ferdinand Carré, demonstrated an ammonia/water refrigeration machine in 1859, and in 1860 Ferdinand received the first U.S. patent for a commercial absorption unit **[21].**

Vapor absorption refrigeration system is actually an alternative of conventional vapor compression cycle. This cycle uses heat instead of electricity to produce cooling system. The demand of electricity consumption is getting high day by day. As the naturel resources are the major foundation in electricity generation. Thus, a prominent sector of naturel resources .i.e. coal, oil and natural gas is consumed in production of electricity. Also, numerous industrial operations runs over power electricity. There is a serious threat for industrial sectors in term of future power supply. Researcher are Refrigeration is the 15% consumption sector of world's total power generation. So if we able to turn over cooling sector over absorption refrigeration system, we will secure a capital part of naturel reserves. The refrigerants use in vapor compression cycle i.e. Chlorofluorocarbons(CFCs), Hydrochlorofluorocarbons(HCFCs) are harmful for our environment and have a vital role in destruction of Ozone Layer. Vapor absorption refrigeration system using refrigerants less toxic and less harmful to environment.

1.2. Working Principle of Vapor Absorption Refrigeration System:

An Absorption refrigeration system is used heat for circulation of refrigerant throughout the cycle. Refrigerant and absorbent solution present in generator is heated up by an external source of heat i.e. solar collector, engine exhaust gases, boiler exhaust gases etc. Refrigerant gets vaporized and go into condenser by passing through a rectifier. In condenser, heat released into environment. The process of heat loss is isobaric and eventually turns into refrigerant liquid. The high pressure refrigerant liquid will flow downward. Expansion valve will reduce the pressure adiabatically. Low pressure and low temperature saturated refrigerant will enter into evaporator. Low temperature refrigerant will heat up by absorbing heat from environment. This high temperature and low pressure refrigerant vapor will enter into absorber where absorber is already present. High temperature vapors will mix-up by absorber and solution is week. This solution will transfer to generator by a pump and the cycle will be repeated.

Ph diagram of simple Absorption refrigeration cycle:

Ph diagram of simple Absorption refrigeration cycle:

This ph diagram is divided into two cycles. First cycle is dependent upon the absorbent-refrigerant separation phenomenon, indicated by point 1-2-3-4. The second cycle is the cycle in which absorbent and refrigerant are dissolved or bound. This cycle begins from point 1-2-3-4 and ended up at 5-6-7-8 points**. [7]**

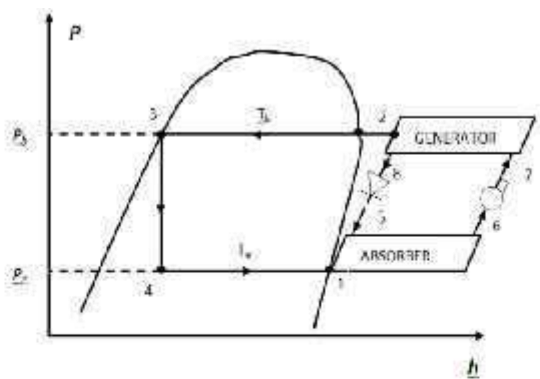

Figure 1.1 The P-h diagram of a simple absorption cycle **[7]**

1.3 Block Diagram of a simple absorption refrigeration system

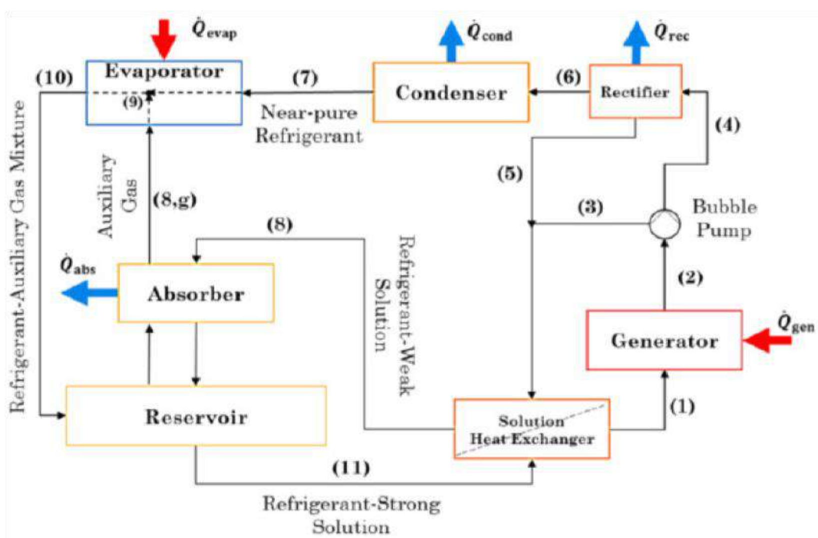

Figure 1.2 A simple block diagram of a DAR system **[22]**

Numerous studies in the literature delve into diffusion absorption refrigeration machines, exploring diverse energy sources [**2–4,8–42**]. Dhindsa [**43**] examined various energy sources, including flat plate collectors, heat storage mediums, motor waste heat, phase change materials, and thermochemical absorption solar hybrid refrigeration systems. The focus of current research lies on absorption chillers. Typically, water/NH3 and LiBr/water serve as common refrigerants, but contemporary researchers often employ alternative fluid mixtures ($LiNO_3/NH_3$, LiBr + $ZnBr_2/CH_3OH$, $LiNO_3$ + KNO_3 + $NaNO_3$/water, LiCl/water, Glycerol/water) to enhance system performance. Authors such as Medrano et al. [44] conducted a refrigeration machine performance study using organic fluid mixtures like trifluoroethanol (TFE)-tetraethylene glycol dimethyl ether (TEGDME or E181) and methanol-TEGDME. Alcântara et al. [**45**] concentrated on developing a mathematical model for simulating the quasi-dynamic behavior of absorption chillers employing $NH_3/LiNO_3$ as the working fluid. Srikhirin et al. [**13**] emphasized the necessity of a "rectifier" in systems using volatile absorbents like water/NH_3 to purify the refrigerant before entering the condenser. Without the rectifier, volatile water would condense in the evaporator, diminishing system performance.

1.4 Main components of Absorption refrigeration System

1. Absorber

Absorber assumes a vital role, a chamber where absorbent and refrigerant are dissolved. Mostly absorber is made of a shell and tube type heat exchanger.

2. Pump

Pump in absorption refrigeration system often referred as a solution pump driven by an external mechanical source. It is responsible for the hydraulic movement of absorbent-refrigerant lethal solution from absorber to generator.

3. Generator

The generator is shell and tube type heat exchanger made with galvanized iron plates welded together to form a cuboidal box of specific dimension. Thermal heat is supplied from external heat source and solution heated up through convection process.

4. Rectifier

This is a crucial component of the cycle designed for the purification of vaporized solution coming from generator. The primary purpose of rectifier is to eliminate absorbent droplet from the vaporized solution and transfer pure vapors to condenser.

5. Condenser

Heat rejection phenomenon occurs in the condenser section. Superheated high pressure high temperature vaporized refrigerant flow in the tube of condenser and dissipate the heat to an external medium. By that thermodynamic latent heat transition, vaporized refrigerant turns into condensed liquid.

6. Expansion valve

This valve serve a critical role in the transition of liquid refrigerant from high pressure liquid to low pressure, low temperature mixture by reducing its pressure.

7. Evaporator

Evaporator is the cooling load production section of cycle. Low pressure, low temperature chilled refrigerant is evaporated by absorbing heat from medium.

1.5. Economical and environmental aspects of absorption refrigeration system

Economical Aspects

1. Energy Efficiency

Absorption refrigeration system mostly shows higher efficiency in terms of energy consumption as compare to vapor compression refrigeration systems. Particularly, in areas where waste heat is available in bulks. This can reduce energy consumption and overall production cast.

2. Diverse Heat Sources

The variety of heat source makes absorption refrigeration system unique and impactful. Solar light, Waste engine exhaust gases and Boiler exhaust gases can utilize as a heat source for generator. This diversity is helpful to recover continues waste energy in term of cooling load production.

3. Reduced Electricity Dependency

In modest areas, electricity crisis is the serious problem of many people. As vapor compression refrigerator works over electricity, it is somehow difficult to produce cooling in such areas. Thus vapor absorption refrigeration system can serve as alternative of vapor compression system. It will lead to reduce electricity consumption and cost savings, particularly in industries with significant cooling effects.

4. Long Lifespan

Although the initial manufacturing cost is relatively high, but due to the long times operations over the years can result in terms of cost savings and running cost.

Environmental Aspects

1. Environmentally Friendly Refrigerants

Refrigerants used in absorption refrigeration systems are relatively less toxic, environmentally friendly and less harmful to surroundings as compare to refrigerant used in vapor compression. These substances have low global warming potential and lower environmental impacts.

2. Minimized Ozone Depletion

The primary benefit of absorption refrigeration system is to protect our ozone layer by utilizing less harmful refrigerants. This contrasts with vapor compression refrigeration system which use relatively high ozone-depleting potential refrigerants.

3. Waste Heat recovery

Absorption refrigeration is significantly used in recovering waste heat during industrial operation. This is the major benefit of absorption refrigeration system over vapor compression system. We also used boiler exhaust gases to produce cooling load in our project. This could not only reduce energy consumption in refrigeration sector, can lead to eliminate the releasing process of harmful exhaust gases from industries to environment.

4. Solar cooling application

One of the most significant benefit of absorption refrigeration system is that we can produce cooling by converting solar light into thermal heat and integrating as heat source. Utilization of renewable energy can lead further in reduction of reliance over non-renewable energy.

5. Reduced Electricity Demand

Refrigeration sector utilizes almost 15% of power production all over the world. By utilizing heat source instead of electricity, absorption refrigeration system contributes in the reduction of energy consumption and electricity demand.

1.6 Problem Statement

Absorption refrigeration system working currently are relatively more costly, low COP, refrigerant being used are highly toxic and harmful to our ozone layer. We will figure out highest Cop in our project and recommend relatively less impactful and environment friendly refrigerant.

1.7 Objectives

- To calculate heat transfer rate for all stages of Absorption Refrigeration System.
- To calculate mass flow rate $\dot{m}$ for all stages of Absorption Refrigeration System.
- To use better refrigerant with better heat source in between from solar energy, WHR from engine exhaust gases and boiler exhaust gases.
- To calculate Cop for system.

1.8 Project Scope

Waste heat recovery is a crucial phenomenon being used for producing cooling load. Industries such as Food production, chemical processing and pharmaceuticals takes advantages by producing cooling from waste exhaust gases.

Renewable based cooling applications are unique, cheaper in terms of long time usage. It reduces electricity dependence in refrigeration sector. Specially in modest areas where availability of electricity is somehow critical, solar powered absorption refrigeration system are highly recommended.

Ozone layer depletion and climate changes are becoming serious threat for human future. The refrigerant used in absorption refrigeration system like Lithium Bromide, Ammonia, and R22 are relatively less harmful to Ozone layer.

1.9 Applications

- Vapor absorption refrigeration system are often used in industrial cooling production particularly in manufacturing facilities, chemical processing , food production and other industrial settings where low cooling is required.
- This system is significantly worked in off-Grid areas where cooling production is restricted due to insufficient electricity.
- This cooling system is definitely worked in high solar irradiation areas.
- Absorption refrigeration systems are used for commercial air conditioning particularly for large cooling load is required.
- Vapor absorption refrigeration system are magnificently used in data centers, hospitals, food and Beverage industry.

Chapter 2

Literature Review

Baby-Jean Robert Mungyeko Bisulandu et all. (2023) This paper proposed an analytical model of various heat sources with different types of absorption refrigeration systems. Research gap between existed models are identified and future instructions are presented. In this research, thermal mechanisms linked with modeling section of heat sources are discussed in details.it summarizes primary methodologies involved in vapor absorption refrigeration cycle, designs and technologies of generator and bulb pump and energy optimization techniques exclusively**.** Applications of vapor absorption refrigeration system in various field are demonstrated accordingly.

Tao Hoi et all. (2023) The waste heat from an ejector-expansion trans-critical Carbon dioxide (EETRCC) is used as a heat source for cooling production. This research employed appropriate thermodynamic models of absorption refrigeration system for feasibility assessment of integrated refrigeration system, along with economic considerations to estimate production overall cost. The results revealed significant better performance of novel integrated framework compared to standalone EETRCC cycle. The estimated cost of produced cooling for the former is obtained as 105.3 $/GJ, while the latter produces cooling with an estimated cost of 102.9$/GJ.

Xinjun Wang et all. (2023) For optimum utilization of energy, Lithium bromide absorption refrigeration system is designed that is used to recirculate the refrigerant at low temperature, and work over industrial residual heat. Firstly, mathematical model of the physical system is designed using the lithium bromide aqueous solution status equation and water, steam status equation for establishing state parameters in the thermodynamic circulation process of system. Secondly, Thermodynamic parameters for each stage are obtained to assist the geometrical design of the system. Finally, the influence of key features on the efficiency of system analyzed to obtain optimum work parameters which can get us highly efficient recovery system.

F. H. Napitupulu et all (2023) This research paper is described the method of waste heat recovery for a diesel engine in details. For this purpose, P-h diagram of ideal absorption refrigeration system is divided into two further cycle. In first cycle 1-2-3-4, separation process is being carried out and in second cycle 5-6-7-8, bonding process is preceding. Temperature of engine exhaust gases is 110°C and generator temperature is set at 90°C. Maximum Cop achieved is 0.45 and graphical representation of results is compiled.

Hong Zhang et all. (2021) In this research, analysis of energy utilization of a solar powered absorption refrigeration Lyophilizer plant in Guangzhou is presented. TRYNSYS is used for simulation process and results are compared with experimental work. The simulation results shows that the freezer dryer using electric heater as heat source are relatively less efficient than freezer dryer using solar absorption refrigeration system as heat source. On 28th July, the solar energy assurance were 74.96% and 236.8kg of coal could be saved and for a month of July solar guarantee rate is 53.48% which can save a quantity of 4790.9 kg of coal. For annual savings, solar assurance rate were figured out as 39.06% and 40657.1Kg of coal consumption can be reduced.

Being Gozmen Sanli et all. (2021) A solar powered absorption refrigeration system is evaluated for satisfaction of cooling requirements of a duplex house located in Isparta province. The cooling load for duplex house were estimated as of 19.3kW. Heat required at generator of absorption refrigeration system approximated as 26.7kW. A vacuum tube solar collector with the efficiency of 59.7% is used as a heat source to meet the specific capacity. Maximum coefficient of performance (COP) is obtained as 0.72.

Devendra Raut et all. (2021) In this study, a latent heat energy storage system is proposed for absorption refrigeration system in absence of solar radiations i.e. in cloudy weather. The system is introduced to keep absorption system in running, whenever solar energy is not available for solar collector. Latent heat energy storage of 2.25 kW charging and discharging time of 3 hours kW is coupled with the system. The designed system gives the High Cop 0.85.

Magdy Mohamed Abou Rayan et all. (2021) developed a conventional ammonia powered absorption refrigeration system empowered by hyperbolic spiral solar collector. The generator temperature is approximately at 140°C and lowest temperature achieved at evaporator is 2°C. For fixed initial conditions, Higher generator temperature and lower evaporator temperature increases the cop and improves the overall performance of cooling unit.

R. Poku1 et all. (2018) This research presents the theoretical model of a cooling system driven by waste heat gases of a Fishing Vessel. Total heat energy available in engine exhaust gases of diesel engine is approximated by energy balance of diesel engine is 55-60% of total input fuel and considered as loss. Thermodynamic analysis of mathematical model is exhibited and heat transfer rate at various section are identified. At generator temperature of 130°C, Coefficient of performance of refrigeration system is calculated as 29.67%.

Nicolás Velázquez-Limón et all (2020) This study investigates a hybrid LiBr-H_2O solar powered absorption system and flash- desalination process. The case study is a 20-room coastal hotel in San Felipe, Mexico. Parameters of solar collector and storage system are measured as $620m^2$ and $30m^3$ respectively. The system demonstrated a desalinated water production of $16.94m^3$ with average performance ratio of 0.83. COP is determined as 13.88% surpassed of traditional single stage absorption refrigeration system.

J.Dardouch1 et all. (2020) This research delve into a numerical investigation of ammonia based single-stage absorption refrigeration system. This setup features a distillation column and integration of a solar heating system. The implications of adding distillation system are manifested as lowered operating temperature, enhanced coefficient of performance, reduced solar collector area.

Rahul Yadav et all. (2016) This paper proposes a better alternative of Electrical based vapor compression system by renewable energy based cooling system. Various research papers are analyzed for the sack of optimum cop and finally an extent of (0.65-0.70) cop is achieved in experiment. This paper suggests analytical usage of solar powered cooling system instead of conventional refrigeration equipment.

S. Sharifi et all (2014) The research focuses on enhancing the performance of a single-effect Lithium bromide/water absorption cooling system, known for utilizing low-grade heat instead of electricity. Employing a multi-objective–multi-variable Genetic Algorithm, the system is optimized for maximum exergetic and energetic efficiencies under varying generator and evaporator temperatures. Correlations between design variables and operational parameters are derived using the Group Method of Data Handling neural network approach. The integration of evacuated tube solar collectors is explored and compared to a similar system. Results show a significant improvement, with energetic and exergetic efficiencies increasing by 9.1% and 3.0%, respectively. This translates to savings of $187 per square meter of solar collector. The optimization involves decreasing the mean temperature of the generator by 6.2 °C and increasing the mean temperature of the evaporator by 1.6 °C, showcasing the potential for improved thermodynamic performance and reduced reliance on high-grade heat sources such as solar energy.

Al A.S LIMA et all (2020) Ammonia vapor cycle and absorbents (H2O, LINO3 and LINO3 + H2O)were studied exhaustively. The main aspects considered in the research were thermodynamic properties of the mixture, numerical correlations, mass transfer, active and passive solar applications, and available prototype and some alternate equipment.

Varun Yadav "et all" (2017) LiBr-H20 used as a refrigerant and powered by solar energy Performance of system analyzed by different factors and operating conditions like solar irradiance, collector, generator, condenser and evaporator temperature. The COP of system was obtained as 0.1 and capacity was 0.01 TAR. This system can be used to develop an air conditioner, Refrigerator or a chiller

Himsar Ambarita a "et all" (2016) Solar powered adsorption refrigeration cycle with generator filled by different adsorbents has been tested in Medan city of Indonesia. The temperature and pressure history and performance were analyzed in 3 different cases. It concluded that for Indonesian conditions and for flat plate type solar collector the pair of activated carbon and methanol is better than aluminium fabrication.

Problem Statement

Absorption refrigeration system working currently are relatively more costly, low COP, refrigerant being used are highly toxic and harmful to our ozone layer. We will figure out highest Cop in our project and recommend relatively less impactful and environment friendly refrigerant.

Objectives

- To calculate heat transfer rate for all stages.
- To calculate mass flow rate $\dot{m}$ for all stages.
- To use better refrigerant with better heat source.
- To calculate Cop for our system.

Chapter No: 3

Methodology

Data collection:

We collected data from Three key refrences

Data collected from Reference 1st:

Heat source: **Exhaust Gas of Combustion Engine**

Absorber Design:

The absorber designed is a heat exchanger with shell and tube type.

The dimension of absorber

Design	Dimension(mm)
Inner diameter of tube	128.1
Outer diameter of tube	141.3
Number of tube	1
Inner diameter of shell	154
Outer diameter of shell	128.1

[7]

Generator Design

The type of heat exchanger of generator used is shell and tube. In the tube is flowing exhaust gas with input temperature of 110˚C and the output temperature of 72.87˚C. Whereas, in the shell is flowing ammonia-water with input temperature of 30˚C and the output temperature of 90˚C.

The dimension of the generator

Design	Dimension(mm)
Inner diameter of tube	110
Outer diameter of tube	130
Distance of tube pitch	230
Buffle distance	70
Number of tube	20
Inner diameter of shell	150
Outer diameter of shell	165

Ref [7] Page no 7

Condenser Design

The condenser using air as a fluid heat sink. The input water temperature in the tube is 28oC and the output water temperature is 28,44oC. Whereas the input ammonia-water temperature in the shell is 39.5oC and the output temperature is 30oC. The dimensions of condenser used consisted of an inner diameter of tube is 6.82 mm, outer diameter of tube is 10.28 mm, distance of tube pitch is 50 mm, the number of pipes is 5 and the intake air velocity is 5 m/s.
[7]

Evaporator Design

The design of evaporators begins by determining the cooling capacity of the evaporator. The cooling capacity is set at 50 W. The fluid to be cooled is air at a temperature of 32°C inside the cooler with dimension 50 cm x 50 cm. The refrigerant used is ammonia. In this study, the temperature of the air to be cooled is expected to achieve a temperature of 0°C.With the temperature of evaporation is 0°C and the temperature of condensation is 35°C. Ref [7] Page no 7

The dimension of the evaporator

Design	Dimension(mm)
Inner diameter of tube	8.7
Outer diameter of tube	9.5
Distance of tube pitch	50
Number of tube	5

[7]

Data collected from Reference 2nd:

Heat source: **Solar Energy**

Design and Fabrication of solar Powered absorption refrigeration cycle.

Construction of condenser

Air cooled fin type condenser is used.

Design	Dimension(mm)
Outer diameter	0.375
Length of copper tube	225

Ref [9] Page no4

Construction of Evaporator

The dimension of Evaporator

Design	Dimension(mm)
Length of tube	48
Breadth of tube	36
Height of tube	25

Ref [9] Page no 4

Construction of Absorber

A copper tube of (OD=0.625mm) with precisely drilled holes is placed on top of an array of horizontal copper tubes (OD=0.375mm) bent from a single pipe such that all of them are connected.

Ref [9] Page no 4

Construction of Generator

The generator is made with galvanized iron plates welded together to form a cuboidal box of dimension 15*15*30mm.The solution is heated in this box with the help of hot water, from the solar collector, flowing inside the helix-shaped copper tube of OD=0.375mm.The box is insulated with a thick asbestos sheet to maintain the high temperature inside the generator**.**

Ref [9] Page no 5

General Parameter of Evacuated Tube Collector

Parameters	**Value**
Tube length	180mm
Tube Diameter,(outer)	58mm
Absorptive Coating Material	Cu/SS-ALN
Glass Material	Borosilicate Glass 3.3
Vacuum Range	<=5*10^-3Pa
Total No. of tubes used in the collector	3

Ref [9] Page no 5

Data collected from reference 3rd

Heat source: Boiler Exhaust gases.

Parameters	**Value**
Main steam Pressure	130 bar
Main steam Temperature	540°C
Flue Gas Outlet Temperature	140°C
Theoretical air quantity	6.411Nm3/kg
Theoretical flue gas quantity	6.923Nm3/kg
Cold air Temperature	30°C
Hot Primary air temperature	279°C

Method Used for Analysis

1st Method : **Analytical Method**

The ***Analytical Method*** is a generic process combining the power of the Scientific Method with the use of formal process to solve any type of problem. It has these six steps:

1. Identify the problem to solve.

2. Choose an appropriate process. (THE KEY STEP)

3. Use the process to hypothesize analysis or solution elements.

4. Accept, reject, or modify the hypothesis.

5. Implement the solution.

6. Continuously improve the process as opportunities arise.

2nd Method : Qualitative analysis methods

Qualitative analysis is used to understand words, ideas, and experiences. You can use it to interpret data that was collected:

- From open-ended surveys and interviews, literature reviews, case studies, ethnographies, and other sources that use text rather than numbers.
- Using non-probability sampling methods.

Qualitative analysis tends to be quite flexible and relies on the researcher's judgement, so you have to reflect carefully on your choices and assumptions and be careful to avoid research bias.

Calculatons

Ammonia as a refrigerant and exhaust gase of combustion engine as heat source: Key Reference

The initial stage begins with determining the temperature of the evaporator, condenser, generator and absorber which the evaporator temperature 0°C, the condenser temperature 35°C, the generator temperature 90°C, the absorber temperature 30°C. From the component temperature can be calculated the value of the pressure, enthalpy and entropy. This was calculated from the tables of thermophysical properties of refrigerants and the results are shown in Table.

The values of enthalpy and entropy

Point	Pressure	Enthalpy	Entropy
1	4.294 bar	1461.81 kJ/kg	5.610 kJ/kg.K
2	13.510 bar	366.58 kJ/kg	5.527 kJ/kg.K
3	13.510 bar	1615.07 kJ/kg	5.619 kJ/kg.K
4	4.294 bar	366.48 kJ/kg	1.568 kJ/kg.K

[7]

The load on the evaporator is set at 50 watts on this research. mass flow rate in the evaporator can be calculated from above table:

Q_e = 50 Watt

Mass flow rate = $Qe/(h_1-h_4)$

Mass flow rate = (0.05kW)/(1461.81 kJ/kg – 366.58kJ/kg)

Mass flow rate = 4.56483×10^{-5} kg/s

The condenser Load = $\dot{m} \times (h_3 - h_2)$

$Q_c = 4.56 \times 10^{-5}$ kg/s × (1615 kJ/kg - 366,58 kJ/kg)

Q_c = 0.057 kW

The next stage is to determine the concentration of ammonia-water solution. By using the graph of concentration of ammonia-water, at a pressure of 13.51 bar and a temperature of 90°C obtained ammonia-water solution concentration of 0.533 and the type of concentration is strong. At a pressure of 4.29 bar and a temperature of 35°C is obtained ammonia-water solution concentration of 0.4 and the type of concentration is weak. By knowing the concentrations of ammonia-water solution so that the enthalpy at points 5, 6, 7, and 8 can be obtained.

The values of enthalpy and concentration

Point	**Temperature**	**Concentration**	**Enthalpy**
5	30	0.40	-100 kJ/kg
6	30	0.40	-100 kJ/kg
7	90	0.53	175 kJ/kg
8	90	0.53	175 kJ/kg

[7]

From the law of conservation of mass, then the values of the mass flow rate refrigerant in the generator can be calculated from the equation:

$\dot{m}_6.X_6 = \dot{m}_7.X_7 + \dot{m}_1$

$\dot{m}_7 = \dot{m}_6 - \dot{m}_1$

$\dot{m}_6.X_6 = (\dot{m}_6 - \dot{m}_1).X_7 + \dot{m}_1$

$0.533\dot{m}_6 = (\dot{m}6 - 4.56483 \times 10^{-5})0.4 + 4.56483 \times 10^{-5}$ kg/s

$\dot{m}_6 = 2.05932 \times 10^{-4}$ kg/s

$\dot{m}_7 = 1.60284 \times 10^{-4}$ kg/s

According to the law of conservation of energy, the amount of energy contained in the absorber is:

$Q_a = \dot{m}_8.h_8 + \dot{m}_1.h_1 - \dot{m}_5.h_5$

Q_a = 0.1153kW

The amount of energy contained in the generator is

$Q_g = \dot{m}_2.h_2 + \dot{m}_7.h_7 - \dot{m}_6.h_6$

Q_g = 0.1224kW

Coefficient of Performance:

COP $= Q_e/Q_g$

= 0.1224kW/0.05kW

COP = 0.426 **[7]**

Ammonia as a refrigerant and Boiler Exhaust gases as heat source:

The initial stage starts with determining the temperature of the evaporator, condenser, generator, and absorber. The evaporator temperature is 0°C, the condenser temperature is 45°C, the generator temperature is 105°C, the absorber temperature is 40°C. . From the component temperature can be calculated the value of the pressure, enthalpy and entropy. This was calculated from the tables of thermophysical properties of refrigerants and the results are shown in Table.

The values of enthalpy and entropy

Point	Pressure	Enthalpy	Entropy
1	4.295	1444.4 kJ/kg	5.340
2	17.85	396.8 kJ/kg	1.443
3	17.85	1474.3 kJ/kg	4.826
4	4.295	181.2 kJ/kg	0.715

Ref [18] Page no 2

The load on the evaporator is set at 65 watts on this research. mass flow rate in the evaporator can be calculated from above table:

Q_e = 65 Watt

Mass flow rate = $Q_e/(h_1-h_4)$

Mass flow rate = (0.065kW)/(1444.4kJ/kg-181.2kJ/kg)

Mass flow rate = 5.14×10^{-5} kg/s

The condenser load = $\dot{m} \times (h_3 - h_2)$

$= 5.14 \times 10^{-5}$ kg/s × (1473.3 kJ/kg – 396.8kJ/kg)

Q_c = 0.0553kW

The next stage is to determine the concentration of ammonia-water solution. By using the graph of concentration of ammonia-water, at a pressure of 17.85 bar and a temperature of 105°C obtained ammonia-water solution concentration is 0.56 and the type of concentration is strong. At a pressure of 4.29 bar and a temperature of 45°C is obtained ammonia-water solution concentration of 0.44 and the type of solution is weak. By knowing the concentrations of ammonia-water solution so that the enthalpy at point 5,6,7,and 8 is obtained.

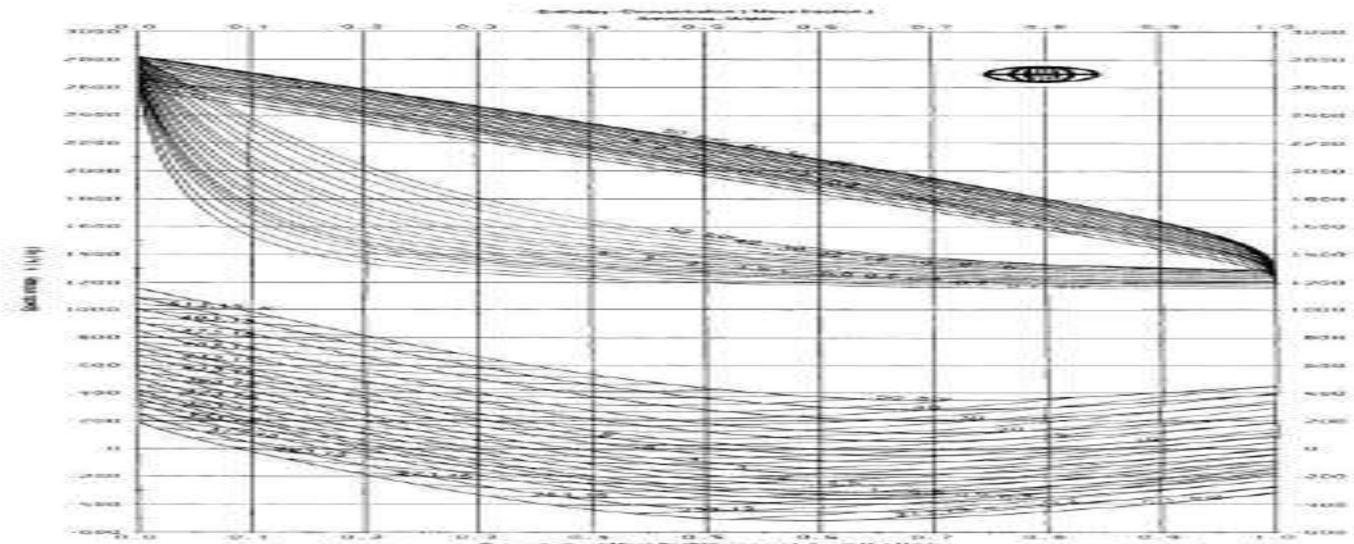

Fig [3.1] **[12]**

Table. The value of enthalpy and concentration.

Point	Temperature	Concentration	Enthalpy
5	40	0.44	-80 kJ/kg
6	40	0.44	-80 kJ/kg
7	105	0.56	220 kJ/kg
8	105	0.56	220 kJ/kg

[12]

From the law of conservation of mass, mass flow rate of refrigerant in the generator can be calculated from the equation.

$\dot{m}6.X6 = \dot{m}7.X7 + \dot{m}1$

$\dot{m}7 = \dot{m}6 - \dot{m}1$

$\dot{m}6.X6 = (\dot{m}6 - \dot{m}1).X7 + \dot{m}1$

$0.56\dot{m}6 = (\dot{m}6 - 5.14 \times 10^{-5})0.44 + 5.14 \times 10^{-5}$ kg/s

$\dot{m}6 = 2.4014 \times 10^{-4}$ kg/s

$\dot{m}_7 = 1.70273 \times 10^{-4}$ kg/s

According to the law of conservation of energy, the amount of energy contained in the absorber is:

$Qa = \dot{m}8.h8 + \dot{m}1.h1 - \dot{m}5.h5$

$Q_a = 0.1234$kW

The amount of energy contained in the generator is

$Qg = \dot{m}2.h2 + \dot{m}7.h7 - \dot{m}6.h6$

$Q_g = 0.1594$kW

Coefficient of Performance:

COP = Qe/Qg

= 0.1224kW/0.05kW

Cop = 0.4062

Ammonia as a refrigerant and Solar energy as heat source:

The initial stage starts with determining the temperature of the evaporator, condenser, generator, and absorber. The evaporator temperature is 4°C, the condenser temperature is 30°C, the generator temperature is 64°C, the absorber temperature is 20°C. . From the component temperature can be calculated the value of the pressure, enthalpy and entropy. This was calculated from the tables of thermophysical properties of refrigerants and the results are shown in Table.

Point	**Pressure**	**Enthalpy**	**Entropy**
1	**4.975 bar**	**1448.5 kJ/kg**	**5.288 kJ/kg.K**
2	**11.7 bar**	**323.1 kJ/kg**	**1.204 kJ/kg.K**
3	**11.7 bar**	**1468.9 kJ/kg**	**4.984 kJ/kg.K**
4	**4.975 bar**	**199.7 kJ/kg**	**0.782 kJ/kg.K**

[18]

The load on the evaporator is set 5.25kWatt on this research.

Qe = 5.25kW

Mass flow rate in the evaporator:

Mass flow rate = Qe/(h_1-h_4)

Mass flow rate = (5.25kW)/(1448.5kJ/kg-199.7kJ/kg)

Mass flow rate = 4.2×10^{-3} kg/s

The condenser load = ṁ × (h_3 – h_2)

= 4.2×10^{-3} kg/s × (1468.9 kJ/kg – 323.1kJ/kg)

Qc = 4.7871kW

The next stage is to determine the concentration of ammonia-water solution. By using the graph of concentration of ammonia-water, at a pressure of 11.7 bar and a temperature of 64°C obtained ammonia-water solution concentration is 0.66 and the type of concentration is strong. At a pressure of 4.275 bar and a temperature of 20°C is obtained ammonia-water solution concentration of 0.57 and the type of solution is weak. By knowing the concentrations of ammonia-water solution so that the enthalpy at point 5,6,7,and 8 is obtained

The values of enthalpy and concentration are obtained by using the graph of concentration of Ammonia-water as shown in Fig.1

Point	**Temperature**	**Concentration**	**Enthalpy**
5	20	0.57	-160
6	20	0.57	-160
7	64	0.66	180
8	64	0.66	180

[12]

ṁ6.X6 = ṁ7.X7 + ṁ1

ṁ7= ṁ6 - ṁ1

$\dot{m}6.X6 = (\dot{m}6- \dot{m}1).X7 + \dot{m}1$

$0.66\dot{m}6 = (\dot{m}6 – 4.24 \times 10\text{-}3)0.66 + 4.24 \times 10\text{-}3$ kg/s

$\dot{m}6 = 2.06 \times 10\text{-}2$ kg/s

$\dot{m}7 = 1.643 \times 10\text{-}2$ kg/s

According to the law of conservation of energy, the amount of energy contained in the absorber is:

$Qa = \dot{m}8.h8 + \dot{m}1.h1 - \dot{m}5.h5$

Qa = 12.24kw

The amount of energy contained in the generator is

$Qg = \dot{m}2.h2 + \dot{m}7.h7 - \dot{m}6.h6$

Qg = 18.33kW

<u>Coefficient of Performance:</u>

COP = Qe/Qg

= 18.33kW/5.25kW

Cop = 0.28

H_2o as a refrigerant and Solar Energy as heat source: [3]

The operating temperatures chosen in °C

Generator Temperature, Tg =60°C

Condenser Temperature, Tc = 28°C

Absorber Temperature, Ta =21°C

Evaporator Temperature, Te =5°C

Capacity of the system or Refrigerating Effect (Qe)= 1.5ton = 5.25kW

Calculation of Enthalpy (h) at every designated point of the system: Enthalpy of pure water and of superheated water vapors at any temperature can be determined from steam tables. Enthalpies of solutions are calculated from Lithium bromide (LiBr) and Water Pressure-Temperature-ConcentrationEnthalpy(P-T-ξ-h) Chart.

Calculation of Heat transfers for each component

Evaporator:-Applying the Energy balance Qe = Refrigerating effect = 5.25kW

$= m(h_{10} - h_9) = m \times (2509.96 - 117.30)$ m =

5.25/ (2509.96- 117.30) or m =

2.19421×10^{-3} kg/s = mass flow rate of refrigerant.

Circulation Ratio $\lambda = \xi WS/(\xi SS - \xi WS)$ $\lambda = 0.48/(0.56-0.48) = 6$ therefore,

mss.= $\lambda \times m = 13.1652 \times 10^{-3}$kg/s

and mws=$(1+\lambda)m = (1+6) \times 2.1942 \times 10^{-3} = 15.3594 \times 10^{-3}$ kg/s

Absorber: Applying the Energy balance

Q_a=mh10+mssh6-mwsh1

$= (2.19421 \times 10^{-3} \times 2509.96) + (13.1652 \times 10^{-3} \times -178) - (15.354 \times 10^{-3} \times -170)$

= 577435W = **5.7743 KW**

Solution Heat Exchanger (HX) Energy balance for Heat Exchanger,

mws$\times(h_3 \times - h_2)$=mss$\times(h_4 - h_5)$

$= 15.3594 \times 10^{-3} \times (h_3 + -170) = 13.16526 \times 10^{-3} \times (-108+178)$

h3=110.0041 KJ/kg

Generator Q_g = mh_7 + $mssh_4$ - $mwsh_3$ = $(2.19421 \times 10^{-3} \times 2609.655) + (13.1652 \times 10^{-3} \times -108) - (15.3594 \times 10^{-3} \times -110.0041)$ = 59938W = **5.993KW**

Condenser $Q_c = m(h_7 - h_8)$

$= 2.19421 \times 10^{-3} \times (2609.655-117.30)$ = 54687W = **5.4687kW**

Thus, **COP** = Q_E/ Q_G

= 5250/5993 = **0.876** **[3]**

Table I: Li-Br-Water Enthalpy-Pressure-Temperature-Concentration

State Points	Temp.in °C	Pressure in mm of Hg	Enthalpy h ,Kj/kg	Concentration ξ
7	60	28.50	2609.65	-
8	28	28.50	117.30	-
9	28	6.54	117.30	-
10	5.0	6.54	2509.96	-
1	21	6.54	-170.0	0.48
2	21	28.50	-170.0	0.48
3	52.25	28.50	-110.004	0.48
4	60	28.50	-108.0	0.56
5	21	28.50	-178.0	0.56
6	21	6.54	-178.0	0.56

[3]

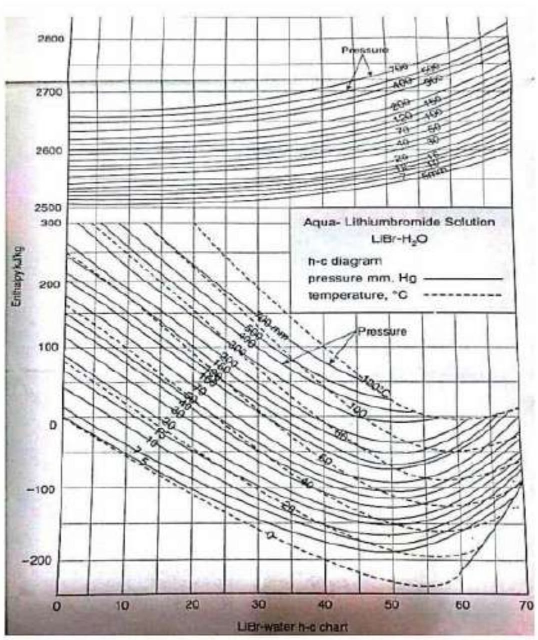

Fig.4-LiBr-H_2O Pressure-Temperature Concentration-Enthalpy Chart

Fig [3.2] **[3]**

H_2o as a refrigerant and Boiler Exhaust gases as heat source:

The initial stage starts with determining the temperature of the evaporator, condenser, generator, and absorber. The evaporator temperature is 0°C, the condenser temperature is 45°C, the generator temperature is 105°C, the absorber temperature is 40°C. . From the component temperature can be calculated the value of the pressure, enthalpy and entropy. This was calculated from the tables of thermophysical properties of refrigerants and the results are shown in Table

The value of enthalpy and entropy

Point	**Pressure**	**Enthalpy**	**Entropy**
1	**0.00617 bar**	**2500.9 kJ/kg**	**9.1556 kJ/kg.k**
2	**0.0955 bar**	**188.44 kJ/kg**	**0.6386 kJ/kg.K**
3	**0.0955 bar**	**2582.4 kJ/kg**	**8.1633 kJ/kg.K**
4	**0.00617 bar**	**0.001 kJ/kg**	**0.001 kJ/kg.K**

Ref

[5] page no 872

The load on the evaporator is set at 65 watts on this research.

Qe = 65Watt

Mass flow rate in the evaporator

Mass flow rate = $Qe/(h_1-h_4)$

Mass flow rate = (0.065kW)/(2500.09kJ/kg-0.001kJ/kg)

Mass flow rate = 2.59×10^{-5} kg/s

The condenser Load = $\dot{m} \times (h_3 - h_2)$

$$= 2.59 \times 10^{-5} \text{ kg/s} \times (2582.4 \text{ kJ/kg} - 188.44 \text{kJ/kg})$$

Qc = 0.062kW

The next stage is to determine the concentration of Libr-water solution. By using the graph of concentration of LiBr-water, at a pressure of 0.0955 bar and a temperature of 105°C obtained LiBr-water solution concentration is 0.44 and the type of concentration is strong. At a pressure of 0.00617 bar and a temperature of 40°C is obtained LiBr-water solution concentration of 0.38 and the type of solution is weak. By knowing the concentrations of LiBr-water solution so that the enthalpy at point 5,6,7,and 8 is obtained.

Point	Temperature	Concentration	Enthalpy
5	40	0.38	100 kJ/kg.K
6	40	0.38	100 kJ/kg.K
7	105	0.44	260 kJ/kg.K
8	105	0.44	260 kJ/kg.K

Ref [8]

Page no 16

Mass flow rate of refrigerant in the generator can be calculated from Table:

$\dot{m}_6.X_6 = \dot{m}_7.X_7 + \dot{m}_1$

$\dot{m}_7 = \dot{m}_6 - \dot{m}_1$

$\dot{m}_6.X_6 = (\dot{m}_6 - \dot{m}_1).X_7 + \dot{m}_1$

$0.44\dot{m}_6 = (\dot{m}_6 – 2.59 \times 10^{-5})0.4 + 2.59 \times 10^{-5}$ kg/s

$\dot{m}_6 = 2.676 \times 10^{-4}$ kg/s

$\dot{m}_7 = 2.417 \times 10^{-4}$ kg/s

According to the law of conservation of energy, the amount of energy contained in the absorber is:

$Q_a = \dot{m}_8.h_8 + \dot{m}_1.h_1 - \dot{m}_5.h_5$

Q_a = 0.08839kW

The amount of energy contained in the generator is

$Q_g = \dot{m}_2.h_2 + \dot{m}_7.h_7 - \dot{m}_6.h_6$

Q_g = 0.10335kW

Thus, COP of the cycle is

COP = Qe/Qg

= 0.065kJ/kg/0.10335kJ/kg

COP = 0.63

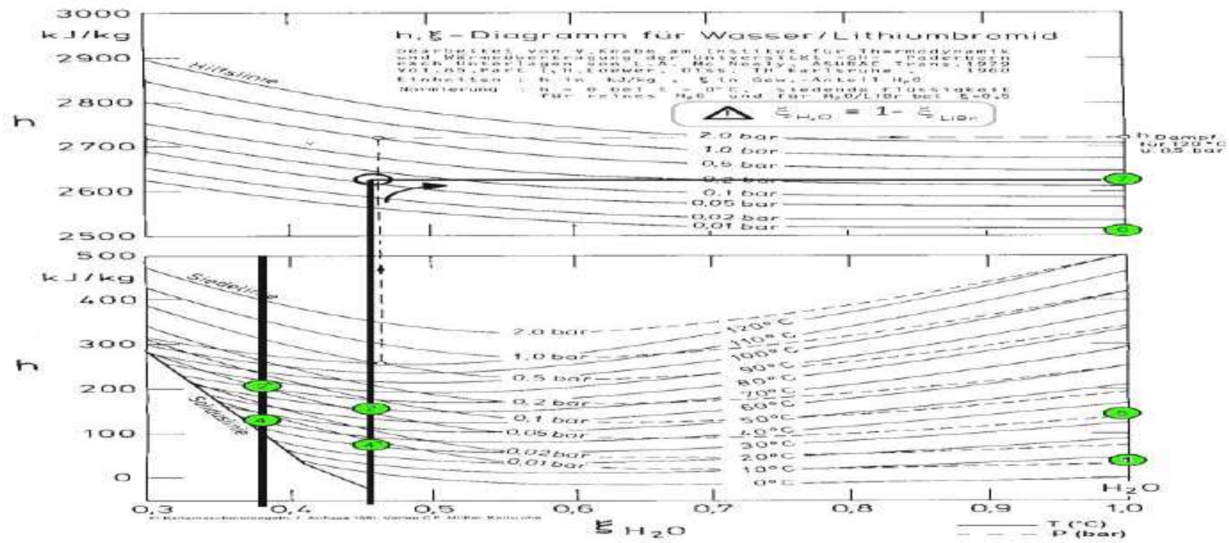

Figure 3.3 Schéma de Merkel-Bosnjakovic Enthalpie/température/ concentration en eau pour le cycle frigorigène de LiBr/H2O[1]. [8]

H_20 as a refrigerant and Engine Exhaust gases as heat source:

The initial stage starts with determining the temperature of the evaporator, condenser, generator, and absorber. The evaporator temperature is 0°C, the condenser temperature is 35°C, the generator temperature is 90°C, the absorber temperature is 30°C. . From the component temperature can be calculated the value of the pressure, enthalpy and entropy. This was calculated from the tables of thermophysical properties of refrigerants and the results are shown in Table.

Table. The values of enthalpy and entropy

Point	**Pressure**	**Enthalpy**	**Entropy**
1	0.00617 bar	2500.9 kJ/kg	9.1556 kJ/kg.K
2	0.05629 bar	146.6 kJ/kg	0.5051 kJ/kg.K
3	0.05629 bar	2564.6 kJ/kg	8.3517 kJ/kg.K
4	0.00617 bar	0.002 kJ/kg	0.0001 kJ/kg

[5]

The load on the evaporator is set at 50 watts on this research.

Qe = 50Wattt

Mass flow rate in the evaporator

Mass flow rate **=** Mass flow rate = $Qe/(h_1-h_4)$

Mass flow rate = (0.05kW)/(2500.9kJ/kg-0.001kJ/kg)

Mass flow rate = 1.99×10^{-5} kg/s

The condenser load = $\dot{m} \times (h_3 - h_2)$

$= 1.99 \times 10^{-5}$ kg/s × (2564.6 kJ/kg – 146.4kJ/kg)

= 0.048kW

The next stage is to determine the concentration of LiBr-water solution. By using the graph of concentration of LiBr-water, at a pressure of 0.056 bar and a temperature of 90˚C obtained ammonia-water solution concentration is 0.55 and the type of concentration is strong. At a pressure of 0.006 bar and a temperature of 30˚C is obtained LiBr-water solution concentration of 0.44 and the type of solution is weak. By knowing the concentrations of LiBr-water solution so that the enthalpy at point 5,6,7,and 8 is obtained.

The values of enthalpy and concentration

Point	Temperature	Concentration	Enthalpy
5	30	0.44	90
6	30	0.44	90
7	90	0.55	230
8	90	0.55	230

[8]

From the law of conservation of mass, mass flow rate of refrigerant in the generator can be calculated from the table.

$\dot{m}_6.X_6 = \dot{m}_7.X_7 + \dot{m}_1$

$\dot{m}_7 = \dot{m}_6 - \dot{m}_1$

$\dot{m}_6.X_6 = (\dot{m}_6 - \dot{m}_1).X_7 + \dot{m}_1$

$0.55\dot{m}_6 = (\dot{m}_6 - 1.99 \times 10^{-5})0.44 + 1.99\times 10^{-5}$ kg/s

$\dot{m}6 = 1.27 \times 10^{-4}$ kg/s

$\dot{m}7 = 1.07 \times10^{-4}$ kg/s

According to the law of conservation of energy, the amount of energy contained in the absorber is:

$Qa = \dot{m}_8.h_8 + \dot{m}_1.h_1 - \dot{m}_5.h_5$

Qa = 0.05264

The amount of energy contained in the generator is

$Qg = \dot{m}_2.h_2 + \dot{m}_7.h_7 - \dot{m}_6.h_6$

Qg = 0.072kW

<u>Coefficient of Performance:</u>

COP = Qe/Qg

= 0.05kW/0.072kW

Cop = 0.69

R22(chlorodifluromethane) as a refrigerant and engine exhaust gases as a heat source

The initial stage starts with determining the temperature of the evaporator, condenser, generator, and absorber. The evaporator temperature is 0°C, the condenser temperature is 35°C, the generator temperature is 90°C, the absorber temperature is 30°C. . From the component temperature can be calculated the value of the pressure, enthalpy and entropy. This was calculated from the tables of thermophysical properties of refrigerants and the results are shown in Table.

Point	**Pressure**	**Enthalpy**	**Entropy**
1	4.979 bar	405.09 kJ/kg	1.17422 kJ/kg.K
2	13.4 bar	242.88 kJ/kg	1.7016 kJ/kg.K
3	13.4 bar	415.30 kJ/kg	1.1499 kJ/kg.K
4	4.979 bar	0.002 kJ/kg	1.003 kJ/kg

[10]

Mass flow rate = Mass flow rate = Qe/(h_1-h_4)

Mass flow rate = (0.05kW)/(405.09kJ/kg-200kJ/kg)

Mass flow rate = 1.83×10^{-5} kg/s

The condenser load = $\dot{m} \times (h_3 - h_2)$

= 1.83×10^{-5} kg/s × (415.30 kJ/kg – 242.88kJ/kg)

= 0.055kW

Point	Temperature	Concentration	Enthalpy
5	30	0.48	-95
6	30	0.48	-95
7	90	0.39	145
8	90	0.39	145

[10]

The next stage is to determine the concentration of LiBr-water solution. By using the graph of concentration of LiBr-water, at a pressure of 0.056 bar and a temperature of 90°C obtained ammonia-water solution concentration is 0.48 and the type of concentration is strong. At a pressure of 0.006 bar and a temperature of 30°C is obtained LiBr-water solution concentration of 0.39 and the type of solution is weak. By knowing the concentrations of LiBr-water solution so that the enthalpy at point 5,6,7,and 8 is obtained

From the law of conservation of mass, mass flow rate of refrigerant in the generator can be calculated from the table.

$\dot{m}_6.X_6 = \dot{m}_7.X_7 + \dot{m}_1$

$\dot{m}_7 = \dot{m}_6 - \dot{m}_1$

$\dot{m}_6.X_6 = (\dot{m}_6 - \dot{m}_1).X_7 + \dot{m}_1$

$0.48\dot{m}_6 = (\dot{m}_6 - 1.83 \times 10^{-5})0.39 + 1.83 \times 10^{-5}$ kg/s

$\dot{m}6 = 1.21 \times 10^{-4}$ kg/s

$\dot{m}7 = 1.05 \times 10^{-4}$ kg/s

According to the law of conservation of energy, the amount of energy contained in the absorber is:

$Qa = \dot{m}_8.h_8 + \dot{m}_1.h_1 - \dot{m}_5.h_5$

Qa = 0.87kW

The amount of energy contained in the generator is

$Qg = \dot{m}_2.h_2 + \dot{m}_7.h_7 - \dot{m}_6.h_6$

Qg = 0.092kW

<u>Coefficient of Performance:</u>

COP = Qe/Qg

= 0.05kW/0.092kW

Cop = 0.54

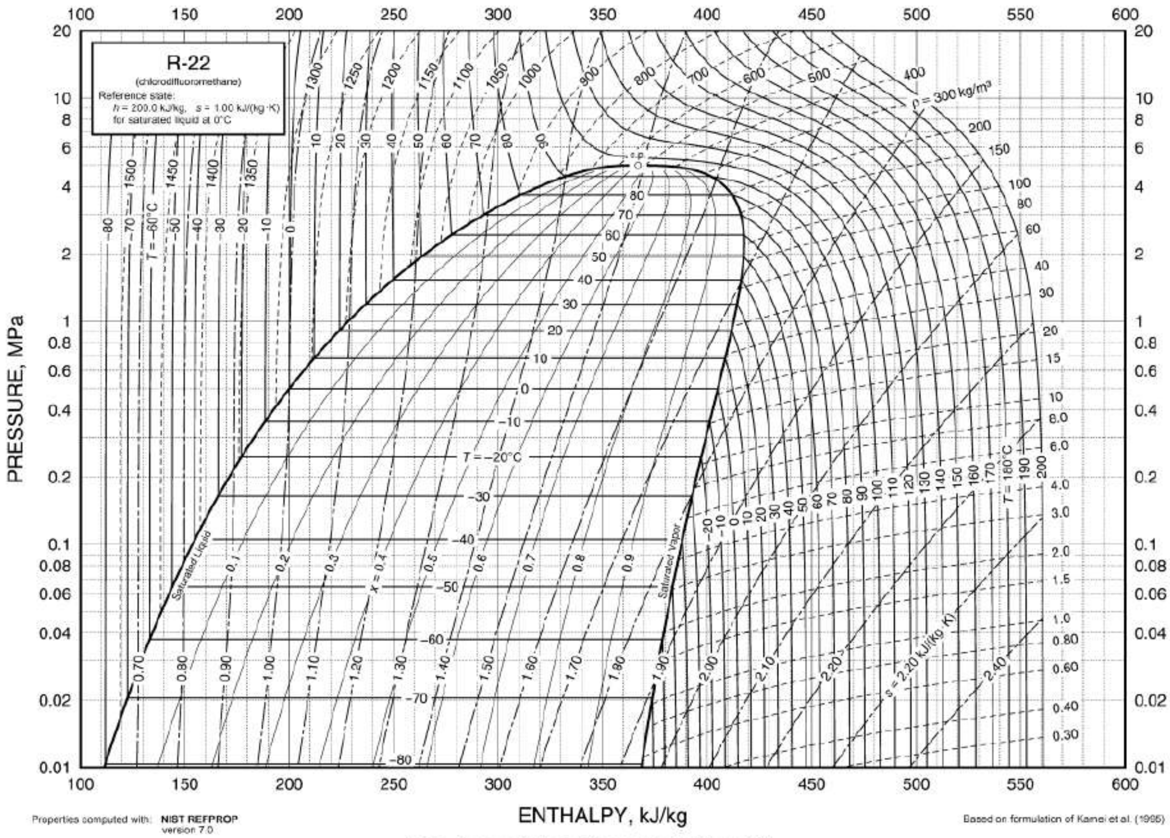

Fig. 2 Pressure-Enthalpy Diagram for Refrigerant 22

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Fig [3.4] **[10]**

R22(chlorodifluromethane) as a refrigerant and Boiler exhaust gases as a heat source

The initial stage starts with determining the temperature of the evaporator, condenser, generator, and absorber. The evaporator temperature is 0°C, the condenser temperature is 45°C, the generator temperature is 105°C, the absorber temperature is 40°C. . From the component temperature can be calculated the value of the pressure, enthalpy and entropy. This was calculated from the tables of thermophysical properties of refrigerants and the results are shown in Table

Point	**Pressure**	**Enthalpy**	**Entropy**
1	4.979 bar	405.09 kJ/kg	1.177 kJ/kg.K
2	17.74 bar	278.88 kJ/kg	1.719 kJ/kg.K
3	17.74 bar	527.30 kJ/kg	1.1534 kJ/kg.K
4	4.979 bar	2.07kJ/kg	1.0009 kJ/kg

[10]

The load on the evaporator is set at 65 watts on this research.

Qe = 65Watt

Mass flow rate in the evaporator

Mass flow rate = Qe/(h_1-h_4)

Mass flow rate = (0.065kW)/(405.09kJ/kg-2.07kJ/kg)

Mass flow rate = 2.33×10^{-5} kg/s

The condenser Load = ṁ × (h_3 – h_2)

$$= 2.33 \times 10^{-5} \text{ kg/s} \times (527.30 \text{ kJ/kg} - 278.44\text{kJ/kg})$$

Qc = 0.072kW

The next stage is to determine the concentration of Libr-water solution. By using the graph of concentration of LiBr-water, at a pressure of 17.74 bar and a temperature of 105°C obtained LiBr-water solution concentration is 0.53 and the type of concentration is strong. At a pressure of 4.979 bar and a temperature of 40°C is obtained LiBr-water solution concentration of 0.42 and the type of solution is weak. By knowing the concentrations of LiBr-water solution so that the enthalpy at point 5,6,7,and 8 is obtained.

Point	Temperature	Concentration	Enthalpy
5	30	0.53	90
6	30	0.53	90
7	90	0.42	230
8	90	0.42	230

Ref[10] page no 3

From the law of conservation of mass, mass flow rate of refrigerant in the generator can be calculated from the table.

$\dot{m}_6.X_6 = \dot{m}_7.X_7 + \dot{m}_1$

$\dot{m}_7 = \dot{m}_6 - \dot{m}_1$

$\dot{m}_6.X_6 = (\dot{m}_6 - \dot{m}_1).X_7 + \dot{m}_1$

$0.53\dot{m}_6 = (\dot{m}_6 - 2.33 \times 10^{-5})0.42 + 2.333\times 10^{-5}$ kg/s

$\dot{m}6 = 1.291 \times 10^{-4}$ kg/s

$\dot{m}7 = 1.167 \times10^{-4}$ kg/s

According to the law of conservation of energy, the amount of energy contained in the absorber is:

$Qa = \dot{m}_8.h_8 + \dot{m}_1.h_1 - \dot{m}_5.h_5$

Qa = 0.12kW

The amount of energy contained in the generator is

$Qg = \dot{m}_2.h_2 + \dot{m}_7.h_7 - \dot{m}_6.h_6$

Qg = 0.152kW

Coefficient of Performance:

COP = Qe/Qg

= 0.065kW/0.152kW

Cop = 0.43

R22(chlorodifluromethane) as a refrigerant and Solar energy as a heat source

The operating temperatures chosen in °C

Generator Temperature, Tg =60°C

Condenser Temperature, Tc = 28°C

Absorber Temperature, Ta =21°C

Evaporator Temperature, Te =5°C

Point	Pressure	Enthalpy	Entropy
1	5.43 bar	478.9 kJ/kg	1.267 kJ/kg.K
2	14.87 bar	289.7 kJ/kg	1.219 kJ/kg.K
3	14.84 bar	630.6 kJ/kg	1.1934 kJ/kg.K
4	5.43 bar	2.67 kJ/kg	1.129 kJ/kg

Ref[10] page no 3

Mass flow rate in the evaporator

Mass flow rate = $Qe/(h_1-h_4)$

Mass flow rate = (5.27kW)/(478.9kJ/kg-2.67kJ/kg)

Mass flow rate = 4.41×10^{-5} kg/s

The condenser Load = $\dot{m} \times (h_3 - h_2)$

= 4.41×10^{-5} kg/s × (630..30 kJ/kg – 289.84kJ/kg)

Qc = 5.98kW

The next stage is to determine the concentration of Libr-water solution. By using the graph of concentration of LiBr-water, at a pressure of 14.87 bar and a temperature of 68°C obtained LiBr-water solution concentration is 0.41 and the type of concentration is strong. At a pressure of 5.43 bar and a temperature of 21°C is obtained LiBr-water solution concentration of 0.28 and the type of solution is weak. By knowing the concentrations of LiBr-water solution so that the enthalpy at point 5,6,7,and 8 is obtained.

Point	Temperature	Concentration	Enthalpy
5	21	0.28	-88
6	21	0.28	-88
7	68	0.41	195
8	68	0.41	195

Ref[10] page no 3

From the law of conservation of mass, mass flow rate of refrigerant in the generator can be calculated from the table.

$\dot{m}_6.X_6 = \dot{m}_7.X_7 + \dot{m}_1$

$\dot{m}_7 = \dot{m}_6 - \dot{m}_1$

$\dot{m}_6.X_6 = (\dot{m}_6 - \dot{m}_1).X_7 + \dot{m}_1$

$0.41\dot{m}_6 = (\dot{m}_6 – 4.41 \times 10^{-5})0.28 + 4.41\times 10^{-5}$ kg/s

$\dot{m}6 = 1.234 \times 10^{-4}$ kg/s

$\dot{m}7 = 1.456 \times 10^{-4}$ kg/s

According to the law of conservation of energy, the amount of energy contained in the absorber is:

$Qa = \dot{m}_8.h_8 + \dot{m}_1.h_1 - \dot{m}_5.h_5$

Qa = 6.6kW

The amount of energy contained in the generator is

$Qg = \dot{m}_2.h_2 + \dot{m}_7.h_7 - \dot{m}_6.h_6$

Qg = 8.8kW

<u>Coefficient of Performance:</u>

COP = Qe/Qg

= 5.52kW/8.8kW

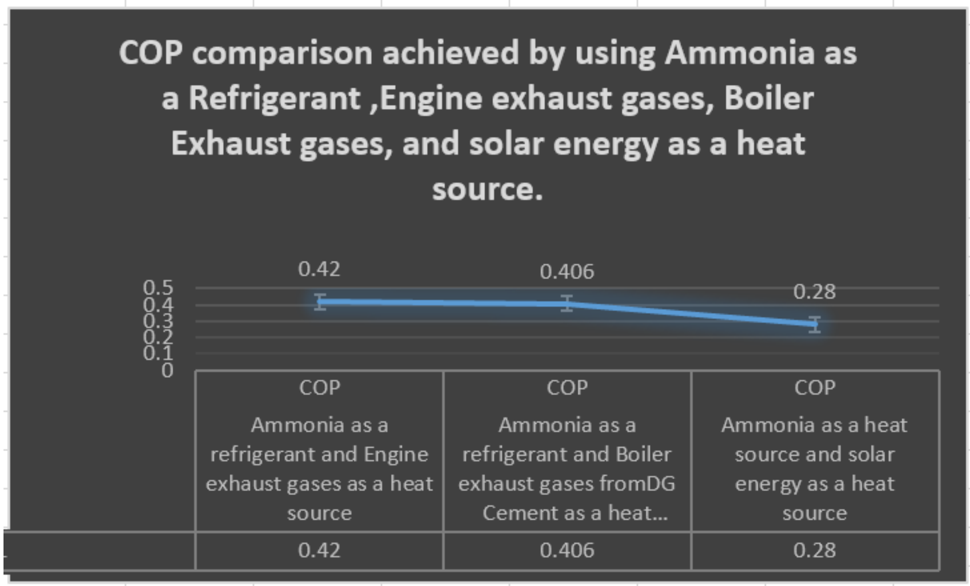
Cop = 0.56

Chapter no 4

Results and Discussion

COP comparison achieved by using Ammonia as a refrigerant, engine exhaust gases , Boiler exhaust gases and solar energy as a heat source.

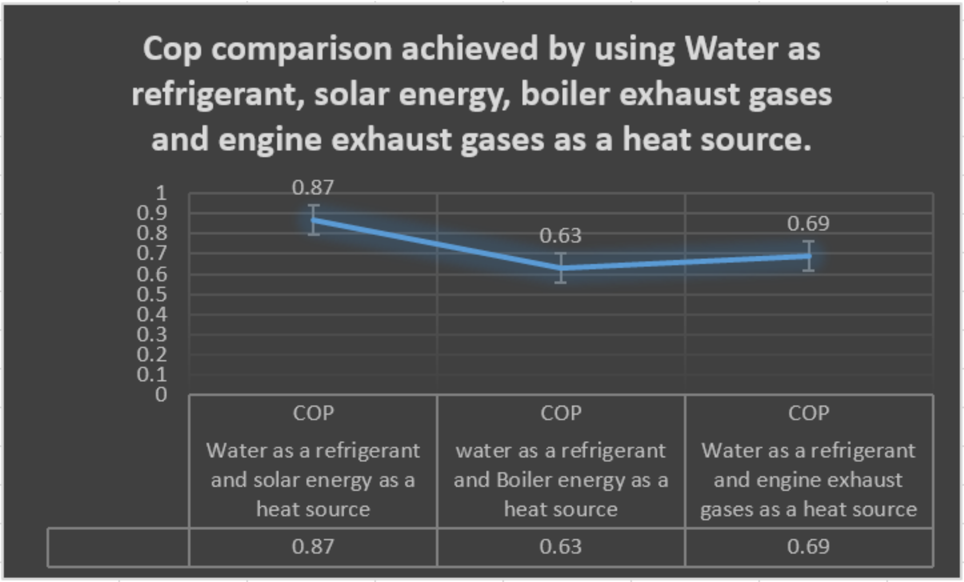
The highest cop by using ammonia as a refrigerant is achieved by key reference who use exhaust gases of a diesel engine as a heat source for heating generator solution. Second highest cop by using ammonia as a refrigerant is achieved with boiler exhaust gases and lowest cop is achieved with solar energy.



Graph [3.1] COP comparison between Ammonia powered absorption refrigeration systems using various heat sources.

COP Comparison achieved by using Water as a Refrigerant and solar energy, boiler exhaust gases and engine exhaust gases as a heat source.

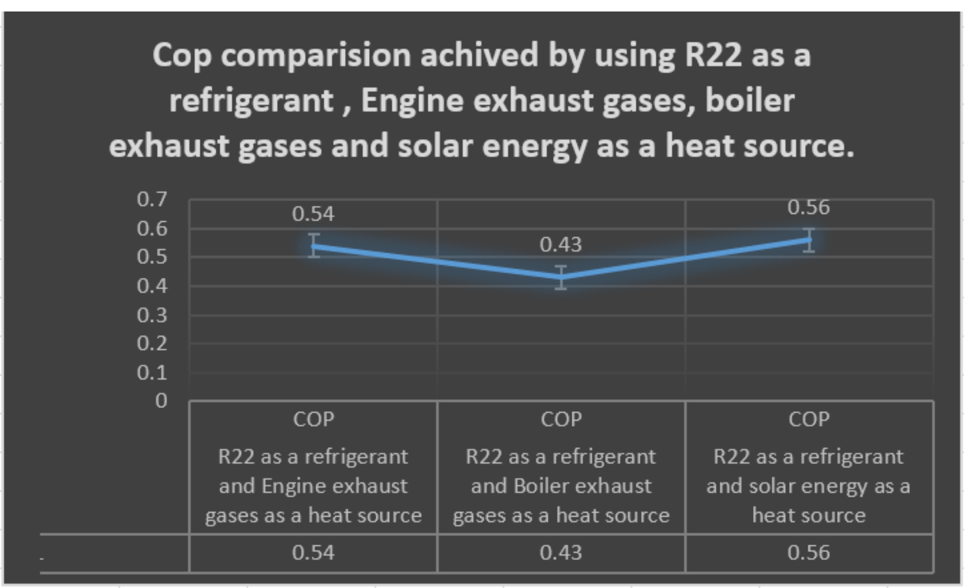
The highest cop for LiBr-water absorption system is achieved with solar energy, 2^{nd} highest cop is achieved with boiler exhaust gases and low cop is achieved with engine exhaust gases of a diesel engine.



Graph [4.2] COP Comparison between LiBr-Water absorption refrigeration system using various heat sources.

COP Comparison achieved by using R_{22} as a refrigerant and solar energy, boiler exhaust gases and engine exhaust gases as a heat source.

The highest cop for R_{22} Refrigerant is achieved with solar energy, 2nd highest cop is achieved with engine exhaust gases and lowest cop is achieved with boiler exhaust gases.



Graph 4.3 COP Comparison between R_{22} absorption refrigeration system using various heat sources.

Comparison between highest cop achieved by all three refrigerants.

Libr-Water solution absorption system is significantly more efficient with highest Cop.

R22 is 2nd highest Cop and Ammonia powered absorption system are less efficient with lowest Cop.

Graph [4.4] Comparison between highest COP achieved by using different refrigerants with various heat sources.

Conclusion

In conclusion, basis on the analytical study of vapor absorption refrigeration system is that:

1. All three refrigerants are relatively different within its thermophysical properties and chemical behavior.

2. Currently, Major sector of absorption cooling applications is used Ammonia as a refrigerant which has serious implications on ozone layer and also low COP.

3. Libr-H_2o and R22-Dimethylether Tetraethylene Glycol Pairs has low environmental impacts.

4. There are a proposed mathematical model for recovering waste heat gases from DG CEMENT POWER PLANT in terms of cooling production.

5. LiBr-H_2o based absorption refrigeration system are recommended as a renewable cooling production system.

Suggestions:

- **Proposed mathematical model based on DG Cement Data can be used for Waste Heat recovery from Boiler Exhaust gases for cooling production.**
- **LiBr-Water Absorption Refrigeration system could be a good alternative of conventional refrigeration and air conditioning system.**
- **This system could be significantly impactful for Environmental effects and utilization of renewable energy for refrigeration purposes.**

Chapter no 5

Conclusion

In conclusion, basis on the analytical study of vapor absorption refrigeration system is that:

1. All three refrigerants are relatively different within its thermophysical properties and chemical behavior.

2. Currently, Major sector of absorption cooling applications is used Ammonia as a refrigerant which has serious implications on ozone layer and also low COP.

3. Libr-H_2o and R22-Dimethylether Tetraethylene Glycol Pairs has low environmental impacts.

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5. LiBr-H_2o based absorption refrigeration system are recommended as a renewable cooling production system.

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