A

PROJECT REPORT

ON

SOLAR POWERED PORTABLE VAPOUR ABSORPTION SYSTEM

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE

OF

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

SUBMITTED BY

ANIRUDDHA SAVARGAONKAR (PRN – 16070125015)
NIKHIL GUDADHE (PRN – 16070125035)
MIHIR JOSHI (PRN – 16070125046)
KEYUR RAJOPADHYE (PRN – 16070125053)

UNDER THE GUIDANCE OF
PROF. VIKAS GULIA

॥वसुधैव कुटुम्बकम्॥

SYMBIOSIS INSTITUTE OF TECHNOLOGY

A CONSTITUTENT OF SYMBIOSIS INTERNATIONAL (DEEMED)UNIVERSITY

Pune - 412115

2020

A

PROJECT REPORT

ON

SOLAR POWERED PORTABLE VAPOUR ABSORPTION SYSTEM

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE

OF

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

SUBMITTED BY
ANIRUDDHA SAVARGAONKAR (PRN – 16070125015)
NIKHIL GUDADHE (PRN – 16070125035)
MIHIR JOSHI (PRN – 16070125046)
KEYUR RAJOPADHYE (PRN – 16070125053)

UNDER THE GUIDANCE OF
PROF. VIKAS GULIA

॥वसुधैव कुटुम्बकम्॥

SYMBIOSIS INSTITUTE OF TECHNOLOGY

A CONSTITUTENT OF SYMBIOSIS INTERNATIONAL (DEEMED)UNIVERSITY

Pune - 412115

2020

CERTIFICATE

The review report entitled "**Solar Powered Portable Vapour Absorption Refrigeration System**" is delivered and submitted by the following students of VIII Semester for partial fulfillment of requirement for the degree of B.Tech in Mechanical Engineering of Symbiosis International (Deemed) University during academic year 2019-20

The material borrowed from other source and incorporated in the thesis has been duly acknowledged and/or referenced.

Student Name	**Mr. Aniruddha Savargaonkar**	**Mr. Nikhil Gudadhe**	**Mr. Mihir Joshi**	**Mr. Keyur Rajopadhye**
PRN	**16070125015**	**16070125035**	**16070125046**	**16070125053**

Colonel (Dr.) AnandPandey

(Head)

(Department of Mechanical Engineering)

Prof. VikasGulia

(Internal Guide)

(Department of Mechanical Engineering)

Examiners:

1) ……………………….

2) ……………………….

3) ……………………….

Date:

Place:

ACKNOWLEDGEMENTS

This project and thesis could not have been completed without the support and guidance of the people of Symbiosis Institute of Technology with whom we had daily interaction. We are extremely thankful to my guide Prof. Vikas Gulia for constantly directing us to the right decision whenever we got caught in a spot of bother. We are thankful to Dr. Anirban Sur for widening our perspective and helping to visualize aspects of the project which we might not have foreseen without his guidance.

Index

Table of Figures

Abstract

A vapour absorption refrigeration system is one of the most effective types of refrigeration systems used all around the world. Downscaling such a system for portable applications can have tremendous future scope. This project not only deals with the portability of such a system, but also the ecological impact. In that, solar energy is used to power this system. This system is known as a 'Solar Thermal Vapour Absorption System'. Solar energy is harnessed by a flat plate collector which in turn helps to heat the working fluid in the generator. Conventionally, an external heat source is used in such systems. A thorough analysis of the refrigerant at every stage of the cycle is carried out in order to find the co-efficient of performance (COP) of this system. With the help of enthalpy-concentration diagram, a mathematical model of this system has been designed, and the system calculation results were verified by a numerical algorithm.

Introduction

1 Refrigeration –

Refrigeration is defined as the process of cooling a space substance or system to lower and/or maintain its temperature below the ambient temperature. Heat is removed from a low temperature reservoir and transferred to a high temperature reservoir.

There are several types of refrigeration systems; one of these systems is heat operated refrigeration systems which include the vapor absorption system which will be our point of focus in the thesis.

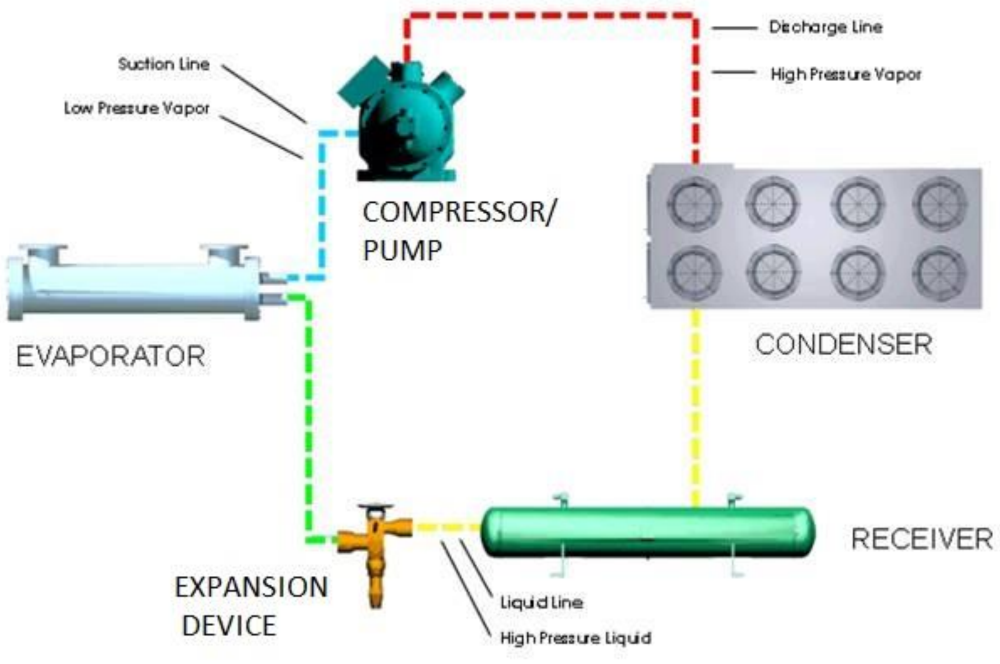


Figure 1 Schematic of Refrigeration system

2 Vapour Absorption Refrigeration System –

This system uses a mixture of two liquids for operation, one is the refrigerant (absorbate) and other is an absorbent. There is a difference of boiling points in the absorbent and absorbate which leads to heat being used to differentiate the two substances and one goes on as a refrigerant in the system. Some common mixtures used are Ammonia-Water and Water-LithiumBromide. Ammonia and Water acts as a refrigerant in the former and later systems respectively.

In this type of system, the task of compressor is achieved by three different devices, which are the absorber, pump and the generator.

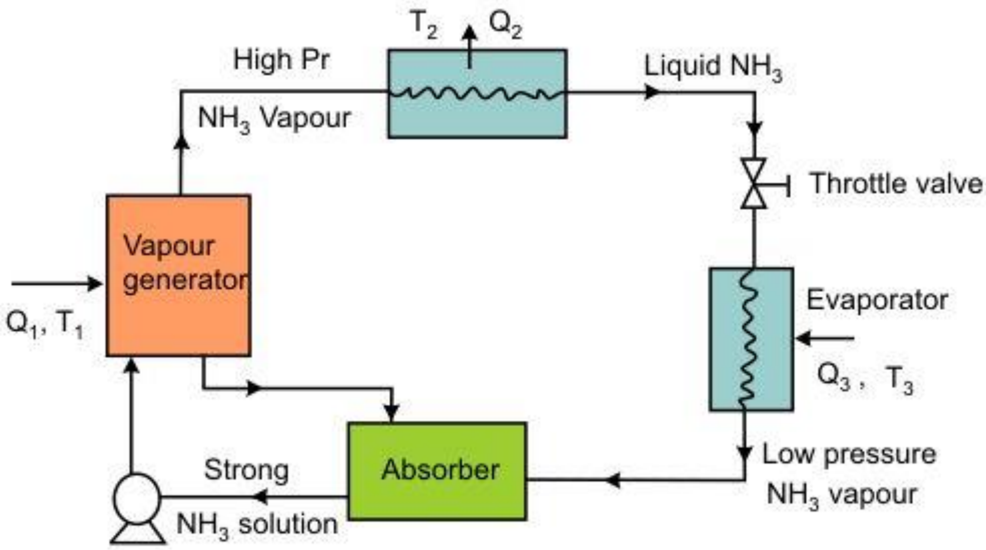


Figure 2 Schematic of Vapour Absorption Refrigeration System

3 Why solar energy?

As it is the case with any machine, efficiency is indirectly proportional to the input. Therefore, an increase in efficiency corresponds to a decrease in consumption. Reduction of consumption of energy for refrigeration purposes, however, cannot only rely on the enhancement of efficiency. Decrease in production of carbon dioxide (CO2) and synthetic refrigerant, can provide a new prospect for solar refrigeration. Considering that cooling demand increases with the intensity of solar radiation, solar refrigeration has been regarded as a rational solution.

Problem Identification

As domestic and industrial refrigeration systems are of major emphasis, portable refrigeration systems are scarcely studied and developed. Solar energy has not been extensively used as a thermal source of energy for the refrigeration purposes. Using heat energy to run the separator in Vapour Absorption Refrigeration System to address the issue of portability has not been studied extensively. In remote areas where electric supply is not reliable, use of such heat-operated refrigeration systems would be very helpful.

Literature Review

D.S. Kim et.al.[1] [2007] examined many systems by means of which refrigeration may be achieved. In their paper, they have considered factors such as type of solar refrigeration technology and juxtaposed it with the cost it takes to make and run such a system. They have forth and compared various systems such as solar-thermal refrigeration, thermo-mechanical refrigeration, absorption refrigeration, adsorption refrigeration, desiccant cooling and electrochemical refrigeration. They mention that although all of these refrigeration systems have their respective pros and cons, all of them share a common problem, i.e. high initial cost. As a result, they have said that solar-electric refrigeration systems and thermo-mechanical refrigeration systems were more costly than solar-thermal refrigeration systems. They have concluded that the best method to obtain refrigeration via solar power is by using a solar-thermal vapour 'absorption' refrigeration system. This is followed by a solar-thermal vapour 'adsorption' refrigeration system. Drawing knowledge from these conclusions, a solar-thermal vapour absorption system is used for the purposes of this project.

IoanSarbu et.al.[2] [2013] have presented a solution to some environmental issues by using solar energy to obtain cooling and refrigeration. In their paper 'Review of solar refrigeration and cooling systems', they mention various types of solar refrigeration systems such as photovoltaic cooling system, thermo-electrical, thermo-mechanical, open and closed sorption and desiccant cooling systems. They have also compared various solar refrigeration technologies. They found that liquid sorption refrigeration systems can use lower temperature heat sources such as solar flat plate collectors therefore; they have the possibility of a drop in the price of the solar constituent of the refrigeration system as compared to closed absorption cycle. In their paper, they have concluded that cooling systems using solar thermal energy are better than conventionally used systems since the working fluids used in such refrigeration systems are environment friendly and do not have a negative influence on nature as the CFC's (Chlorofluorocarbons) in conventional refrigeration systems do. They have made a number of inferences from their comparisons, some of which are that the absorption refrigeration systems are more desirable than the adsorption refrigeration system. This latter conclusion has formed a basis for the justification of use of solar vapour absorption refrigeration system in this paper.

R. S. Agarwal et.al.,[3][1985] The solubility characteristics of Monochloro-difluoromethane (R22) with dimethyl formamide (DMF) have been examined, to check the suitability for vapor absorption refrigeration system. For this, tasks likemeasurement of vapor pressure of mixtures, finding the vapor-pressure data for plotting lnP - 1/T diagram to analyse the system and finding the thermodynamic correlation of vapor-liquid equilibrium were carried out. For vapor-pressure data, a wide range of temperature and compositions was taken and observations were done for pure R22, pure DMF and R22-DMF mixtures. Due to these experiments, it was found that the solubility characteristic of R22 with DMF is very good and can be of great potential for vapor-absorption systems.

A. K. SONGARA et.al.,[4][1998] The performance of HCFC134a- dimethyl acetamide (DMA) solution is investigated and is thermodynamically compared with the previously acclaimed HCFC22-dimethyl acetamide solution in vapor absorption refrigeration system. Effects due to variation in the temperatures of condenser and absorber, generator and evaporator were observed and graphs were plotted against circulation ratio(CR), heat input at generator (Q_G), coefficient of performance(COP) and second law efficiency. During the comparison between the two solutions, it was found thatHCFC22-DMA givesslightly low CRs and yields higher second-law efficiencies; COPs are lower for HFC134a-DMA and can operate at much lower pressures than HCFC22-DMA. The authors concluded by stating that HFC134a-DMA Vapor Absorption Refrigeration Systemcan operate at low heat source temperatures which makes it suitablefor low-potential heat sources such as solar energy and that it can be used if the use of HCFC22-DMA phases out.

Aman Shukla et.al.,[5][2015]This paper emphasizes on the need to minimize the consumption of energy in the industrial areas and for that the authors have suggested the need of using the Vapor absorption refrigeration system by using the heat energy being wasted from the system from the units such as generators, boilers, thermal plants, etc. Here, the aim is to find the performance of a single stage vapor absorption system and hence its reliability for the objective mentioned. For this, the tasks carried out were selection of the suitable refrigerant, thermodynamic analysis, finding the heat transfer of the system with respect to every component, selecting suitable temperatures and operating pressures and hence finding the co-efficient of performance. As a result, COP was found out to be 0.598 and it was concluded that the parameters like generator, condenser, evaporator and absorber temperatures have a great influence on the COP and hence on the reliability of the system.

V.K.Bajpai[6] [2012] Here, the author has the objective of designing and studying the vapor absorption system having unit capacity using solar energy. Flat-plate collector is selected as the reference for the calculations. Condenser pressure and evaporator pressure areconsidered for making the enthalpy-concentration diagram from which the values for the enthalpies are obtained. By using the diagram and taking some assumptions, parameters like mass flow rate of ammonia as refrigerant, heat removed in the evaporator, heat removed in condenser, heat removed from absorber, heat given in the generator, calculations of solar water heater are calculated and thus the coefficient of performance of refrigerating unit and the whole system is calculated which came out to be 0.69 and 0.58 respectively. Thus, it was concluded that solar energy can be used for refrigeration.

Salem M. Osta-Omar et.al.[7][2016] have performed an analysis of an absorption refrigeration system by constructing a mathematical model which uses LiBr/Water (Lithium-Bromide/Water) as a working fluid. In this, Lithim-Bromide is used as an absorbent and water works as the refrigerant. To simplify the modelling and design parameters, they made a few assumptions. The most fundamental one on which the mathematical model of this system heavily relies upon is that there is equilibrium of pressures between the working fluid (Li-Br/Water) in the absorber and the refrigerant (Water) in the evaporator, and also between the working fluid in the generator and refrigerant and the condenser. The results of their experiments show that generator temperature is a key parameter in the design of a vapour absorption refrigeration system. They also conclude that rise in the temperature of generator or drop in the temperature of adiabatic absorber will yield a higher COP. The proposed values for the generator temperature and the absorber temperatures are 80°C & 40°C respectively. This paper had prompted us to consider the variation of COP with generator temperature in this paper.

Research Gap

Research in the general refrigeration and HVAC industry has been carried out extensively with the aim of increasing its capacity with respect to area under refrigeration. Researching the opposite, i.e. reducing the area under refrigeration in an efficient manner, has been of lesser importance compared to the former.

A result of researching methods aimed at increasing the capacity of refrigerated area is to inadvertently make the plant rigid in terms of location. Portable refrigeration systems are scarcely studied and developed.

In the few portable systems which have been developed, they are operational either in automobiles, which take input from the internal combustion engine making them stationary in the automobile as well as dependent on ignition, or in the hospitality sector, where the refrigerators are miniature versions of the domestic sizes and take regular electrical input, which again make them stationary while connected to an electrical outlet.

One of the major gaps in research is to use solar energy for refrigeration purposes. This is due to various reasons; low efficiency being one of them.

Whenever the topic of solar energy is discussed, most of the applications make use of solar panels of photovoltaic cells which convert solar radiation into electrical energy. The amount of consideration and importance given to harnessing the heat energy of solar radiation is given comparatively lesser importance.

Similarly, in the case of refrigeration using solar energy, most of the research done is about the use of solar photovoltaic cells used to run a compressor in a regular electrical refrigeration system. This approach poses complications with the size, scale and portability of the systems while also being less efficient in spite of being relatively expensive. Using heat energy to run the separator in Vapour Absorption System to address issue of portability has not been studied extensively.

There is a predominant conception of refrigeration systems being unavailable in remote areas where some kind of external artificially manufactured source of energy like electricity is unavailable. Developing this ability would be beneficial in many ways, and research on this specific ability has not been as extensive as expected.

Objective

The main objective of the project is to make a portable refrigerator which works on solar energy. The objective method is to adapt the Vapour Absorption Refrigeration System to create a refrigeration system which is small enough to be manually transported easily.

A refrigeration system generally uses a compressor which increases the pressure of the refrigerant, and is usually run on electrical energy. If the system is intended to run on solar energy, there are two methods to make it happen.

One of them is to make use of a photovoltaic cell system to convert solar radiation into electrical energy which in turn would be used to run the compressor. The challenge in this system, apart from the fact that many such systems have already been explored, is that the primary objective of portability is difficult to achieve.

The other option, and one of the main objectives, is to use the heat energy present in solar radiation. For this to take place, the compressor needs to be replaced by three components viz. absorber, generator and a pump. The heat needs to be supplied to the generator (sometimes called separator due to its function of separating the absorbent and refrigerant). This supply of heat can also be done by two ways, directly and indirectly. The indirect way is approximated to have less efficiency and therefore the objective is to use the direct method to provide solar heat to the generator component.

The other objective of portability is expected to be achieved by considering a small but optimal area under refrigeration, which would also be practical enough to store and transport a certain amount of goods. This area should also be enough to house the refrigeration system including its components and tubing.

Methodology

1. **Review of various refrigeration cycles like Vapour Compression Cycle, Vapour Absorption Cycle**.

2. **Study of the compatibility of these refrigeration cycles in conjunction with solar power.**

3. **Detailed study of the Vapour Absorption Cycle**
   The aim of this study was adapting the cycle to be used in a portable solar powered refrigerator.

4. **Checking the feasibility with regards to the prototype development through various perspectives like finance, part availability and adaptation to considered scale.**

5. **Amendments considered due to the identified constraints in the previous point**.
   It was identified that the cost of the prototype would not be economically feasible in the current scenario, and therefore, a decision was taken to progress with the help of a mathematical model of the system to provide proof of concept.

6. **Reviewing the processes required to construct a mathematical model.**

7. **Mathematical Modeling**
   Construction of mathematical model of the system to conduct the calculations.

8. **System Calculations**

9. **Numerical analysis of the system calculations.**

Work Done

1. **Review of various refrigeration cycles like Vapour Compression Cycle, Vapour Absorption Cycle.**

   a. Vapour Compression Cycle

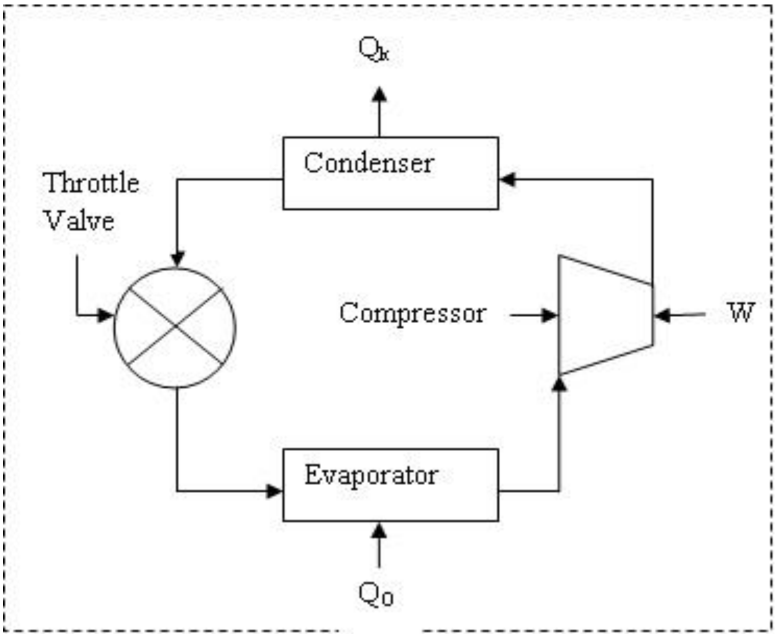
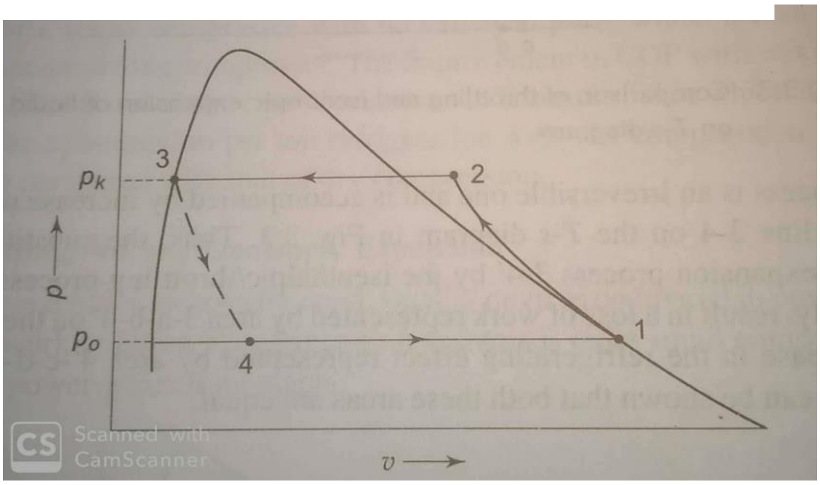


Figure 3 Schematic of Vapour Compression Cycle



1-2 – Isentropic Compression

2-3 Desuperheating and Condensation

3-4 – Isentropic Expansion

4-1 - Evapouration

Figure 4 P-V curve of Vapor Compression Cycle

This cycle follows the schematic shown in the above diagram. This is the most widely used system due to its high coefficient of performance (COP). The trio of Expansion device (outlet) – Evapourator – Compressor (inlet) comprise of Low pressure side of the system whereas, Compressor (outlet) – Condenser comprise of part of the system which has high pressure. The diagram shows a P-v diagram of the cycle.

b. Vapour Absorption Cycle

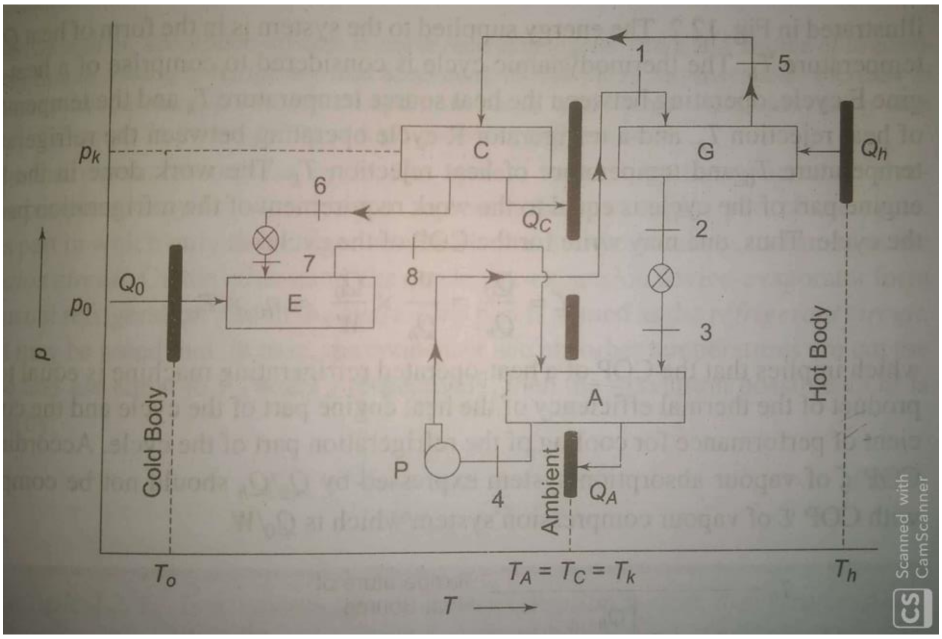


Figure 5 P-T diagram of Vapour Absorption Cycle

It is a heat – operated refrigerating cycle. In this cycle, the function of compression is carried out by three devices – absorber, pump and a generator or a reboiler. The refrigerant is a mixture of two fluids having vast difference in their boiler points. The above diagram shows a P-T diagram which is also a schematic of the cycle.

2. Study of the compatibility of the aforementioned refrigeration cycles in conjunction with solar power

a. The vapour compression cycle makes use of a compressor which is run by an external power supply like electrical or mechanical power. In the considered application of solar power, harnessing considerable solar energy to run a compressor would make the objective of portability redundant.

b. Therefore, using the Vapour Compression cycle would have made the refrigeration system bulky and, therefore, non-portable.

c. Using the Vapour Absorption system allows for circumventing the compressor and hence being independent of the need to convert solar energy to electric power.

d. It therefore allows the system to be compact while harnessing the heat energy present in solar radiation.

3. **Detailed study of the Vapour Absorption Cycle**
   a. Selection of a Refrigerant.
      i. Various refrigerants like ammonia-water, R22-DMF, R134-DMF and Water-LiBr were considered.
      ii. Out of the considered refrigerants, ammonia-water was selected due to favorable factors like procurement feasibility, availability of literature and environmentally friendly nature.
   b. The various thermodynamic processes which are a part of this system were studied.
   c. The parts which are generally required to construct such a system were noted down. These parts include:
      i. Pump – It is required increase the pressure of ammonia-water solution before it enters the generator.
      ii. Generator – It is required to separate the ammonia from the water by using external heat.
      iii. Condenser – It is a heat exchanger which decreases the temperature of ammonia vapours and converts them to liquid.
      iv. Throttling Device –It decreases the pressure and temperature of the refrigerant further before it enters the evaporator.
      v. Evaporator – It is where the cooling takes place. The refrigerant absorbs heat, converts to vapour and then travels to the absorber.
      vi. Absorber – It contains the weak solution of refrigerant which absorbs high temperature refrigerant vapour coming from the evaporator. The solution is then converted to a strong solution, which then travels to the pump where the process repeats itself.
   d. The study also included searching for the availability of these parts in the scale and capacity required for this application.

4. **Checking the feasibility with regards to the prototype development through various perspectives like finance, part availability and adaptation to considered scale.**
   a. The parts which were found were out of the economic feasibility possible in the current scenario.
   b. Some of the parts were unavailable in the required dimension range.

c. Some of the parts were entirely unavailable and would have required to be specially fabricated for the required specifications.

5. **Amendments considered due to the identified constraints in the previous point.**

   The feasibility check revealed that making of a working prototype would not be economically feasible. Therefore, we were advised to turn to creating a mathematical model of this system to provide proof of concept.

6. **Reviewing the processes required to construct a mathematical model.**

   The existing literature on the subject of creating mathematical models of vapour absorption refrigeration systems was studied in order to understand and conduct an independent mathematical modeling study on the considered application and analyze its results to provide proof of concept.

7. Mathematical Modeling –

a. Condenser Pressure – As only pure ammonia enters the condenser, we can get the value of condenser pressure by the saturation table of ammonia refrigerant. The temperature of condenser is 25°C; hence, the corresponding pressure is 10 Bar.

b. Evapourator Pressure – Evapourator is to be maintained at 10°C; hence, its corresponding pressure is 6 Bar.

c. Enthalpy Concentration Chart for the system pressure and temperatures –

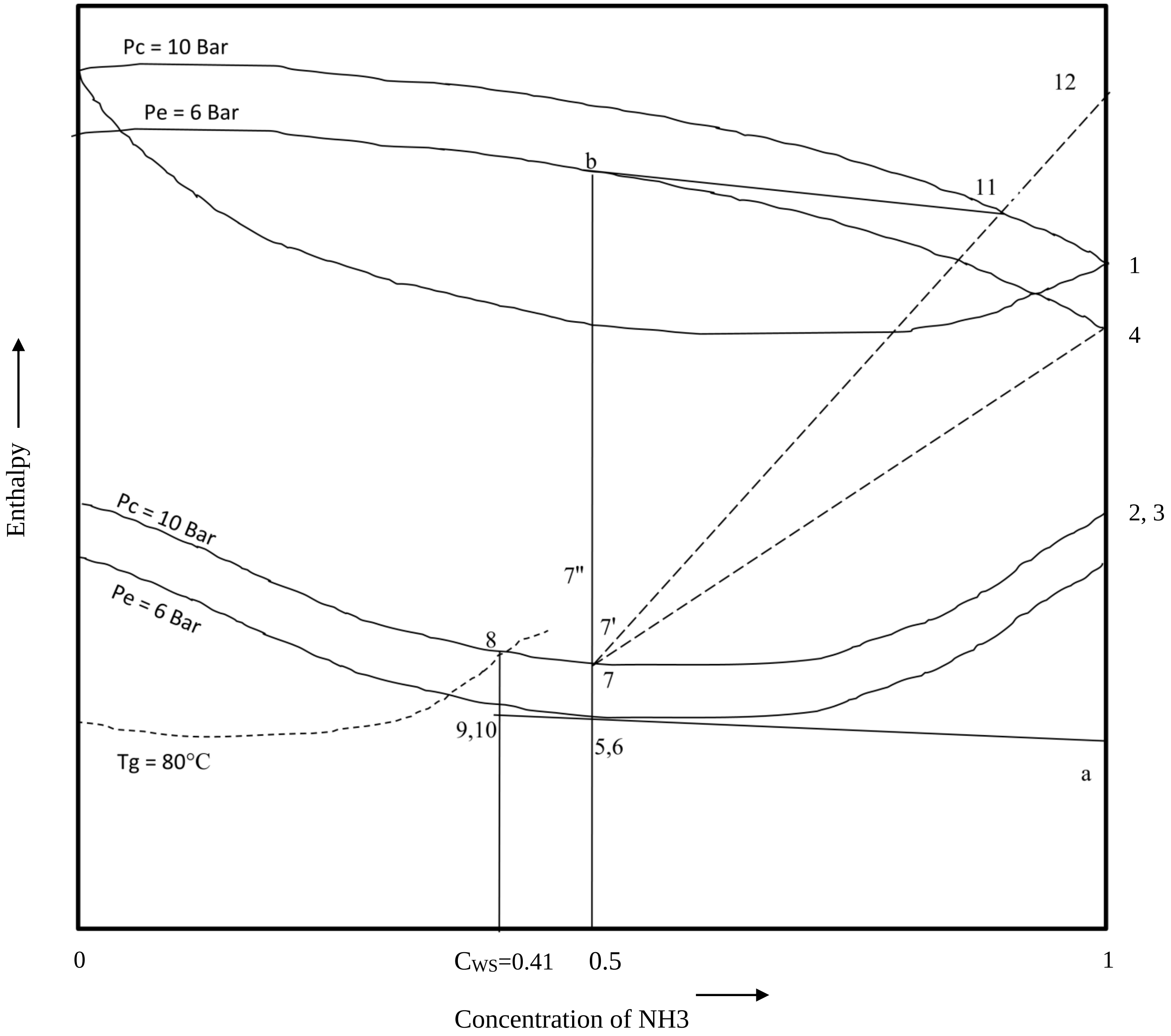


Figure 6 Enthalpy - Concentration Chart

Point 1 – It shows Pure, saturated ammonia vapour at condenser pressure, Pc and at concentration, C=1.

Point 2 – It shows Pure, saturated ammonia liquid at condenser pressure, Pc and at concentration, C=1.

Point 3 – It shows Pure ammonia(wet) at evaporator pressure, Pe and at concentration, C=1, h2=h3 (Isenthalpic Throttling)

Point 4 – It shows Pure, saturated ammonia vapour at evaporator pressure Pe which absorb heat in the evaporator and converts wet vapour to standard vapour.

Enthalpies at the points 1, 2, 3 and 4 can be referred using the enthalpy-concentration chart.

h1 = 1630kJ/kg

h2 = h3 = 430 kJ/kg

h4 = 1620kJ/kg

d. For a portable unit, the refrigeration capacity is taken to be 0.5 TR.

Mr x (h4-h3) = 0.5*210 kJ/min = 105 kJ/min (Mr = Mass flow of refrigerant)

$\therefore$ $\boxed{\textbf{Mr = 0.088 kg/min}}$

e. Temperature of Generator – 50-80°C

- To find the ideal COP, we will take the generator temperature to be 80°C and the amount of heat to be produced is Qg.
- Point 8 is marked on the enthalpy-concentration chart when 80°C line intersects with the 10 bar line.
- Point 8 signifies hot weak concentration liquid with the concentration Cws. Now, Cws=0.418.
- Point 5 can be set; it is the strong solution coming from absorber after absorbing the vapours coming from evaporator.
- C5 can be determined by the degasifying factor (It is the amount of NH3 vapours removed from strong solution in the generator).
- Higher value of this factor is advantageous as higher value averts water from getting evaporated.
- In this system, a mass of 0.088 kg/min is required;

  Now, C5 = Css = 0.418+0.088 = 0.506

$\therefore$ C5 = Css = 0.506

- Point 6 – It shows the condition of solution with concentration equal to C5, but pressure changes from evaporator pressure to condenser pressure as solution is pumped by a pump.
- Point 7 – As the high concentration ammonia solution goes through the Heat Exchanger, its temperature and enthalpy rises but its concentration stays the same and pressure remains condenser pressure, Pc.
- Join point 8 & point 7 and lengthen till it intersects y axis at point ‘a’. Then link point ‘a’ & point 5 and lengthen the line till it intersects vertical line which goes through point 8 and that gives us point 9 & point 10.
- Point 9 – It shows the condition of low concentration liquid coming from heat exchanger, after transferring heat to strong solution, hence enthalpy is decreased.
- Point 10 – It has the same enthalpy as point 9 but at lower pressure Pe.

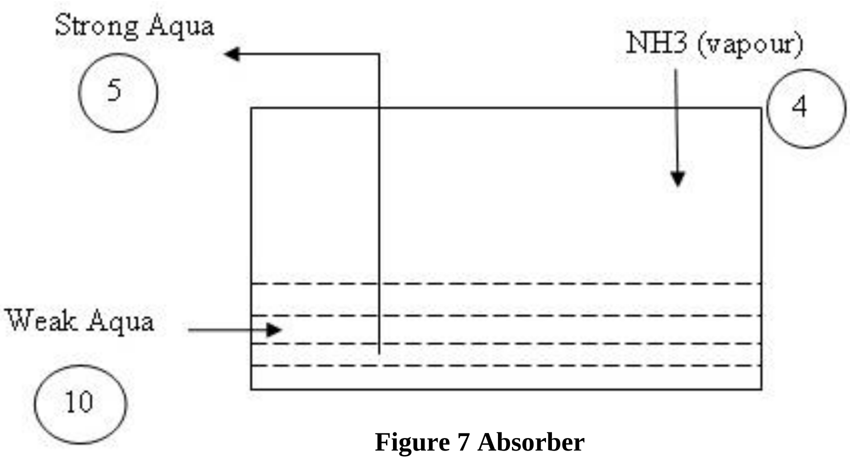


Figure 7 Absorber

- Join point 10 & point 4 and the point where it intersects vertical line from point 7 is named as point 7’.

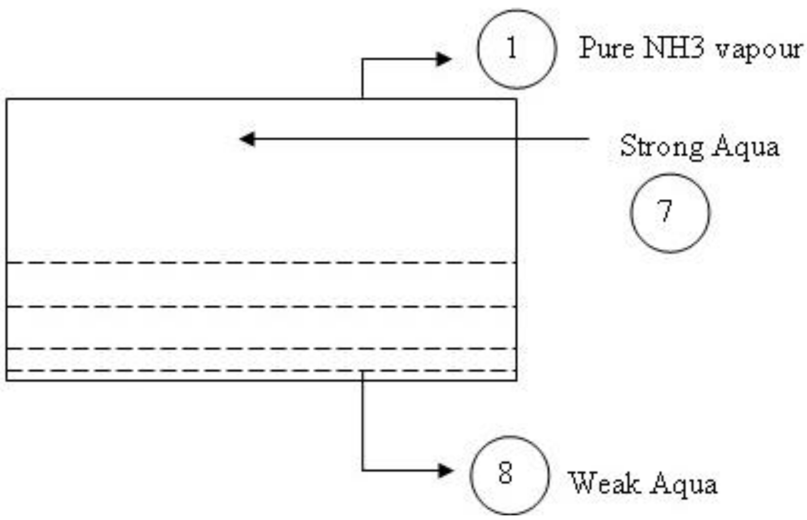


Figure 8 Generator

- Join point 8 & point 1 and name the point where it intersects vertical line from point 7 as point 7".

8. Calculations –

a. Mass flow rate of refrigerant(ammonia) = Mr = 0.088 kg/min

b. Heat removed in the evaporator = Refrigerating effect

$$= Mr \times (h4 - h3)$$

$$Qe = 0.5\ TR = 105\ kJ/min$$

c. Heat removed in condenser = Qc = Mr x (h2 – h1)

$$= Qc = 0.088 \times (1620-430)$$

$$= Qc = 105.6\ kJ/min$$

d. Heat removed from absorber –

When ammonia at point 4 and ammonia solution at point 10 are mixed, it results in the condition given by the point 7' and after losing heat, aqua comes out at point 5.

$$Qa = Mr \times (h7' - h5)$$

Extend the lines 10-7' and 10-5 till 10-7' intersects at point 4 and 10-5 intersects on y-axis on point 'a'.

$$Qa = Mrx\ (h4 - ha) = 0.088 \times (1620 - 70) = 136.4\ kJ/min$$

$$Qa = 136.4\ kJ/min$$

Now, resultant solution is at point 7" and losses heat up to point 5,

Temperature at point 7" = $T_{7''}$ = 82°C (from C-h chart) and T_5 = 25°C.

Water is heated from 25°C to 82°C.

Mw = Mass of cooling water required

Mw x Cp (Ti – To) = 136.4 kJ/min

Mw = 0.57 kg/min

e. Heat added in the generator –

Let Qg be the heat added in generator and Qd be the heat removed from water vapour, then net heat removed per kg of aqua if given by the following equation:

$$Qg - Qd = Mr \times (h7' - h7)$$

As aqua goes in the generator at condition of point 7 and comes out of generator at condition of point 7". By extending the lines 8-7' and 8-7 till the former intersects at point 1 and the latter intersects at point 'a' on y-axis.

$$Qg - Qd = Mr \times (h1 - ha)\ .$$

To find Qd separately, we lengthen the line 7-7” till it intersects auxiliary line of condenser pressure Pc, and we name the point as point ‘b’.

Then, we draw a horizontal line through point ‘b’ which intersects Pc line at point 11 and we name the point where it intersects y-axis as point 12.

$$Qd = Mr \times (h12 - h1) = 0.088 \times (1750 - 1630)$$

$$Qd = 10.56 \text{ kJ/min}$$

$$Qg - Qd = Mr \times (h1 - ha)$$

$$Qg = 147.84 \text{ kJ/min}$$

f. Coefficient Of Performance –

COP of refrigeration unit => $COP = \frac{Qe}{Qg} = \frac{105}{147.84}$

$$COP = 0.71$$

9. NumericalAnalysis –

The system calculations which were done manually were compared using numerical analysis method which was done with the help of python software. The results showed that the system calculations done manually matched with the results of numerical analysis, thus providing the proof of concept.

Results

1. The Coefficient of Performance (COP) obtained by manual calculations is 0.71.
2. The Coefficient of Performance (COP) obtained by numerical analysis is 0.718.
3. Development of a prototype was not feasible due to financial and time constrains.
4. This study shows that as both the COPs are equal, it proves that designing a portable absorption refrigeration system of capacity 0.5 Tons which us powered by Solar (thermal) energy is theoretically viable.

Conclusion

Therefore, after a substantive study of literature regarding vapour absorption refrigeration systems, solar thermal refrigeration and various system calculations, a mathematical model of a 'Solar powered portable refrigeration system' has been designed. The main aim of this project was to determine the coefficient of performance (COP) for a scaled down model of a solar thermal refrigeration system and whether it is desirable. The results show that by manual calculations, the value of COP is 0.71 and the value by using numerical analysis is 0.718. Since this value of COP is viable, it provides the proof of concept for the said mathematical model.

Future scope

1. It is possible to use this mathematical model to develop a working model of the same.
2. The portability of this system can make it easy to carry a refrigerator for people in remote areas with abundant sunlight.
3. In the future, this model can be scaled down further, which can be used for a variety of medical purposes, such as storing vials of insulin for diabetic people.

References

[1] Kim, D. S., & Ferreira, C. I. (2008). Solar refrigeration options–a state-of-the-art review. *International Journal of refrigeration*, *31*(1), 3-15.

[2] Sarbu, I., & Sebarchievici, C. (2013). Review of solar refrigeration and cooling systems. *Energy and buildings*, *67*, 286-297.

[3] Agarwal, R. S., & Bapat, S. L. (1985). Solubility characteristics of R22-DMF refrigerant-absorbent combination. *International journal of refrigeration*, *8*(2), 70-74.

[4] Songara, A. K., Fatouh, M., & Murthy, S. S. (1998). Comparative performance of HFC134a-and HCFC22-based vapour absorption refrigeration systems. *International journal of energy research*, *22*(4), 363-372.

[5] Shukla, A., Mishra, A., Shukla, D., & Chauhan, K. (2015). COP derivation and thermodynamic calculation of ammonia-water vapor absorption refrigeration system. *Journal Impact Factor*, *6*(5), 72-81.

[6] Bajpai, V. K. (2012, July). Design of solar powered vapour absorption system. In *Proceedings of the World Congress on Engineering* (Vol. 3, pp. 4-6).

[7] Osta-Omar, S. M., & Micallef, C. (2016). Mathematical model of a lithium-bromide/water absorption refrigeration system equipped with an adiabatic absorber. *Computation*, *4*(4), 44.

[8] C.P. Arora, "Refrigeration and Air Conditioning".