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# A Review on Vapour Absorption Solar Refrigeration System

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**Abstract**

An up-to-date overview of various technologies which are existing to provide refrigeration from the solar energy is provided. This review covers some evolving technologies in the field of solar absorption refrigeration. Solar thermal systems include thermos-mechanical, absorption, adsorption technology. Comparisons between different refrigerants are made in terms of both efficiency of the energy and feasibility of the economic. Solar electrical and thermo-mechanical systems appear to be more expensive than thermal absorption systems. The total cost of the NH3-H2O water absorption system is estimated to be less expensive than the Li-Br. Solar Vapor absorption systems uses a source of heat to facilitate cooling, distinct from vapor compression systems. The two LPG absorption chillers use a generator attached to the heating element and it operates at single system pressure which doesn't exist any moving parts such as pumps or compressors. This paper compared the performance of VARS used for refrigeration which is below ambient temperature. The most common NH3-H2O solution vapor absorption refrigeration system uses H2O as the absorbent and NH3 as the refrigerant.

## Introduction

Sun is the main source for energy generated by water, fossil fuels and wind. Solar energy is the energy which dies not go extinct. Refrigeration and space cooling are both high-energy process. Preservation demands in cold temperature in various areas are highest in the time of daylight, when the demand for solar energy is widespread; this is especially true during the hot season. Most of the state in India receives plenty of sunlight during the entire year. Therefore the Solar refrigeration is the most applicable technology for India, specifically given the rapid increase in the requirement for energy and the scarcity of electrical power. Cooling is projected to consume approximately 35K MW of electricity for many different applications. Part of these energies are produced by the power plants in zones where electrical energy is readily obtainable, while the remainder is generated by Digital Generator, which will consume a significant amount of highly supported diesel which results in air, noise and high CO2 emissions[1].

A solar-powered system is the one that runs on electrical power generated with the help of sun. Solar-powered cooling systems can keep consumable goods like dairy and meat, cool in hot climatic conditions. Solar refrigerators are most usually used in countries which are developed to help eradicate poverty, to reduce climate change. Plug in refrigeration device with backup digital generators safely stores vaccine in the developed countries, but in countries which are developing, where electric supplies can be unpredictable, alternate refrigeration technology is required [2].

### *Methods of solar refrigeration*

Three ways in which solar energy can be cast-off for preservation are. the solar thermal, solar mechanical, and solar electric methods.

### *Electric Method by using Solar*

Sun light is straight away rehabilitated to DC current via array of solar cell identified as a Photovoltaic panel in the Solar Electric Method. Photovoltaic Cells are semiconductors that convert direct current from solar energy. The generated electric current is deposited in a lead acid battery, although the remaining powers the refrigerator's compressor. This Direct current can either be used to power the compressor's DC motor or converted to AC current and used to power the compressor via an inverter. To stabilise and level the current, a solar controller comprised of capacitors, sensor, and other components might be required. A typical Solar PV system is made up of several parts that are selected created on the structure type, position, and submissions. A charge director, inverter, battery-operated, secondary energy bases, and loads are the main components of a solar Photovoltaic system. PV which will convert the sunlight into direct current. Controls the current and voltage flowing from the PV panel to the battery, preventing overcharging and it will extend battery life. Inverter is a device that will convert the direct current output of the photovoltaic panels to alternating current which can then be used by AC purposes or nourished back into the power grid. A battery is a device that stores energy in order to power electrical appliances later on. Loads include lights, radios, televisions, computers, refrigerators, and other electrical appliances connected to a solar Photovoltaic organization.

***Mechanical Method by using Solar***

To drive the compressor in the Solar Mechanical Method the mechanical power is required. Rankine heat power cycle is used in this process. To vaporise the fluid at high pressure Rankine cycle uses heat exchange with the fluid which will be heated by the solar collector. This process can include a storage tank for high temperature thermal storage. To generate the mechanical power, the vapour will be passed over a piston expander or a turbine. When the pressure exits the expander, it condenses then is pumped return to the boiler to vaporised again. As the temperature of the vaporised fluid entering the expander rises the efficiency of the Rankine cycle increases. on the other hand, solar collector's efficiency decreases as the temperature of the delivered energy rises. High temperatures can be achieved by using intent solar collector that will trail the positions of the sun in more than one dimension. The weight, cost and complexity of system are all disadvantages of using solar trackers. By means of evacuated tube, advanced multi-cover flat plate collectors or with the fluid temperature which ranges from 100°C to 200°C, tracking can be avoided. The intensity of the solar radiation and the difference between the temperature of the incoming fluid and the ambient regulates efficiency of solar collectors. The efficiency of this arrangement is minimum than the efficiency of non-concentrating PV modules used in solar electric systems. Solar mechanical will be useful when light trackers are used, which are only available for large refrigeration systems weighing at least 1000 tonnes.

***Thermal Method by using Solar***

The primary benefit of the Solar Thermal Method over photovoltaic systems is that it utilises more of the incoming sunlight. A traditional PV collector loses 65% of incident light radiation as heat, however solar accumulators captivate over 95% of inbound solar radiation. Due to inefficiencies and losses, entire absorbed energy is not converted to valuable energy. Commercial solar thermal collectors have collection efficiencies that are added to double those of a crystalline PV solar collectors. Solar thermal refrigeration system contains of 4 main apparatus those are a thermal storing tank, solar amasser array, a thermal cooling unit, and a heat exchange system that transfers energy among the components and the refrigerated space. The solar array is chosen based on the temperature required by the refrigeration system. Horizontal plate collectors, evacuated tube accumulators, then low concentration collectors can handle temperatures ranging from 60 to 100 degrees Celsius. Due to the high cost of solar trackers, concentrative collectors are avoided for residential use. The storage intermediate and the desired temperatures influence the type of thermal storage tank chosen. The low environmental impact and high specific heat of water were factors in its selection [2].

## Methodology

By using a small setup (fig 1) of generator/absorber, spread valve, condenser, storage tank and evaporator comprise the solar absorption refrigeration system. A CPC serves as the cooling system's generator/absorber and it functions on an NH3-LiNO2 mixture. During the day, the solar energy incidents on the CPC heats the NH3-LiNO2 mixture in the generator/absorber till it reaches the temperature which is saturated. Ammonia in the solution is then partly evaporated. Ammonia vapour is routed to the condenser and condensed by air or water before being fills the tank. After the sun sets, the NH3 liquid flows through the valve, lowering its temperature and pressure and it causes the cooling effect in the evaporation system. The pressure in this component rises after the NH3 absorbs the heat from water which will be stored in the evaporation system. Pressure and temperature in generator/absorber decrease as the ambient temperature decreases. As a result, the pressures in the components are naturally inverted, and NH3 vapour proceeds to the generator/absorber, wherever NH3 absorbed by the solution which is strong restarts the cycle. [3]

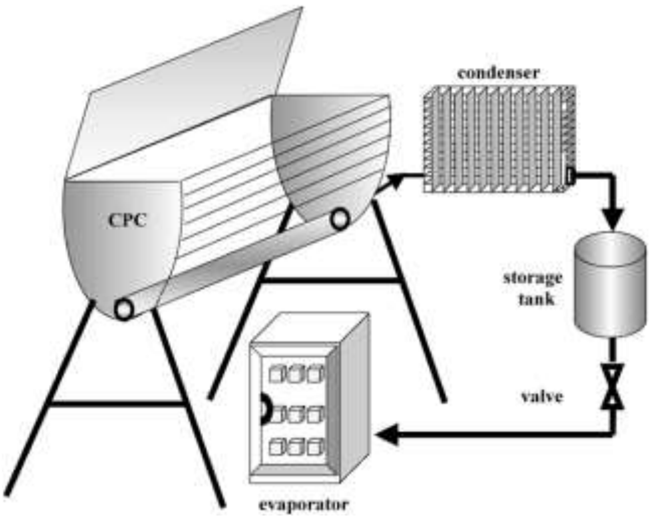



Fig 1. Schematic diagram of intermittent solar vapour absorption system of refrigeration.

Whereas Jasim Abdulateef [4] analysied the thermodynamical properties of NH3-H20, NH3-LiNO2 and NASCN solutions. (fig 2) Low pressure vapor which is generated by the refrigerant from evaporator which will be absorbed by a strong solution of liquid. Pump takes a liquid which is having less pressure dilutes the solution which is present in the absorber, increases the solution pressure which will be in the state of watery. In generators, heat from a temperature source uses solar power.

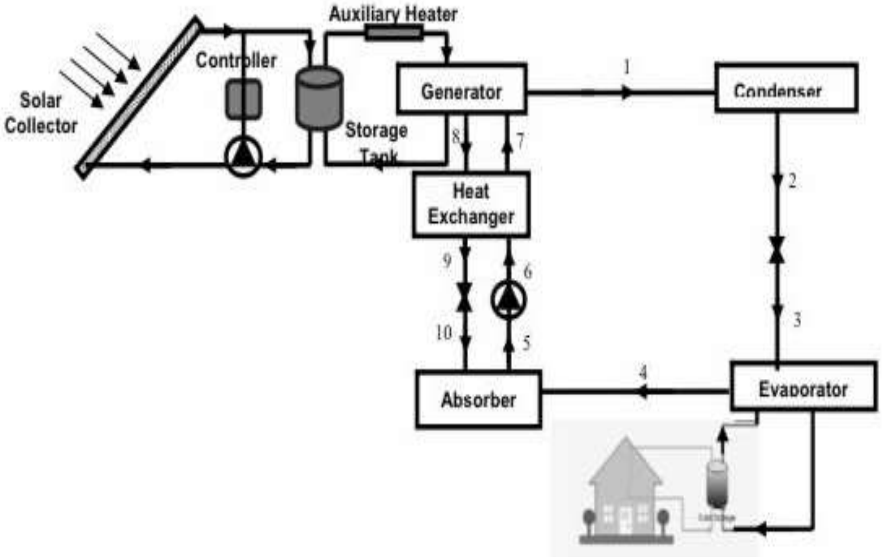



Fig 2. The schematic of the solar absorption system refrigeration

To expel refrigerant vapours in weak solutions. Strong liquid solutions return to absorber via a throttle valve. The use of this throttle valve is mainly to decrease the pressure of the generator/absorber. The high-pressure refrigerant vapor condense the liquid and it arrives at the evaporator through the throttle valve to maintain pressure differential between the condenser, evaporator. To further improve the performance, a solution implemented is adding the heat exchanger to the circuit [4].

S. Alizadeh et al [5] did theoretic studies on the performance of vapour absorption refrigeration cycles of NH3-H20 as refrigerant-absorbent[5].

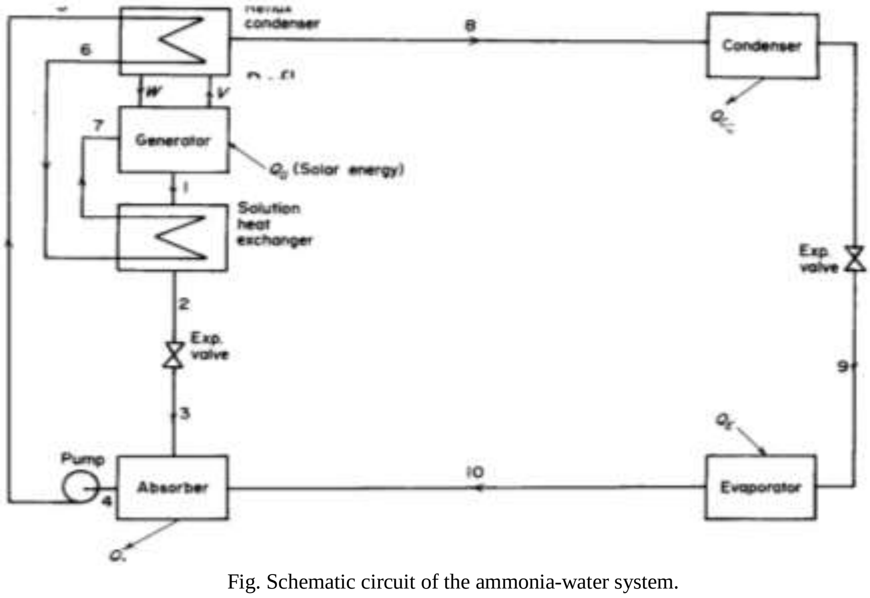
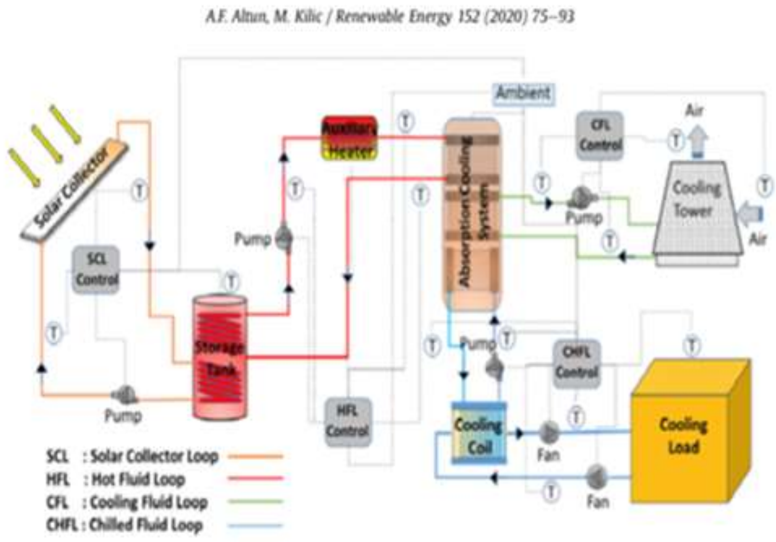



Fig. Schematic circuit of the ammonia-water system.

Altun, M. Kilic[14] did the dynamic simulation on TRNSYS model a single stage high temperature combustion absorption refrigeration cycle .A single file is required is specified in grade level TRNSYS data format. This file contains the normalised full load capacity rate and the design energy involvement rate for numerous values of a Design Load Factor cooling Set/point Temperature, cooled Water Inlet Temperature , and water which is extremely hot through the Inlet Temperature . Taking into the consideration the data of the external files providing in the TRNSYS , inlet will be having extremely hot water temperature which will be ranged between 108.9 degree celsius and 116.1 degrees Celsius and the inlet which is cooled water temperature range is defined approximately 26.7 degree celsius and 32.2 degree celsius . It has been recognised that shrinking the capacity and using current data files which is external in the digital library yields unrealistic results.




Different operating conditions and capacities. Therefore, we use the EES software to model and validate a single-

***Schematic of a single effect ACS***

effect Libr and H20 ACS system. Next, to provide more realistic results, use the EES software to create an external TRNSYS catalog file for the cooler absorption model. The studied single-effect Lithium bromide-H20 ACS as shown above. The working medium is H20 and the Lithium bromide acts as an absorbent. ACS consists of condenser, evaporator, generator, expansion valve pump, absorber, expansion valve and solution heat exchanger. Lithium bromide plus H20 solution will be the absorbent and water will be the coolant. Little pressure of the water vapour supplied from the evaporator will be absorbed by the Lithium- Bromide aqueous solution. On the other hand, the heat of absorption is released into the absorbing medium. A pump conveys the feeble Nacl solution from absorber to the solution of the heat exchanger .The dilute solution will be then heated and it will leave the heat exchanger. Alternatively the simulation of this experiment of the heat exchanger, the sturdy solution exits generator and it will flow through a solution heat exchanger giving heat to the feeble solution and then a strong solution will be entered to the expansion valve and its pressure will be dropped to the pressure of the absorber at the outlet of the valve. The heat input provided by the hot fluid to the generator vaporises some of the solution n the generator and the superheated steam is sent to the condenser .In the condenser heat is transferred to the cooling solution and the saturated water is discharged from the condenser . This water will enter the expansion valve on the side of the refrigerant and its pressure drops with constant enthalpy to the evaporator pressure. The evaporator evaporates the refrigerant while cooling the chilled water.

It has been found by investigating[15]the properties of hybrid nano fluids. The majority of researchers report promising outcomes. The hybrid nano-fluids were found to have optimised properties and proved suitable for the solar system, which requires good temperature performance rheological and optical properties of working fluids. The following section summaries important properties such as optical, temperature performance, rheological, and morphological properties of cross breed nano fluids reported in the latest research articles. Thermal Properties The good thermal abilities of fluids are of paramount importance when used in solar energy applications such as photovoltaic which has the ability to heat the systems and solar collectors. Many numbers of studies are available evaluating the temperature performance of this kind of experiments conductivity or thermal transfer properties of cross breed nano-fluids. Which has conductive properties of Sodium dioxide plus MWCNT/EG hybrid nano-fluids as a function of nano-fluid temperature and concentration. Mistake of the system or the environment conditions during the experiment analysis implied the strong agreement between the experimental and numerical results. Temperature and concentration were varied from 30 to 50 °C degrees celsius and 0.05 to 1.95 volume %, respectively. At 50 °C degree celsius and 1.95 volume%, an increase of up to 22.2% in thermal conductivity TCR was observed. Results of the experiments has shown nonlinear changes in the thermal conductivity of the hybrid nano-fluids as a function of nano-fluid concentration and temperature, Increasing the concentration of the nano fluid increased the number of nanoparticles and dramatically increased the thermal conductivity. Increasing the temperature of the hybrid nano-fluid increased the Brownian motion of the suspended nanoparticles, increased the number of collisions, and increased the thermal conductivity of the hybrid nano fluid. Afraid evaluated the thermal conductivity of f-MWCNT-MgO/EG nano-fluids as a function of temperature and volume concentration of the nano-fluid. It turns out that the experimental and numerical results converge. He found that the TCR increased linearly with increasing nanoparticle concentration. An increase in temperature resulted in an increase in the thermal conductivity of the hybrid nano fluid, whereas the thermal conductivity of EG increased significantly with temperature compared to the hybrid nano-fluid, suggesting a slight decrease in TCR with increasing temperature was recorded The relatively large size of MgO nanoparticles can cause unwanted agglomeration. The decrease in TCR as a function of temperature was attributed to aggregation or clustering of nano fluids which limited the Brownian motion of particles and hindered the number of collisions between nano particle . A 21.3% increase in TCR was observed at 0.6 vol% and 25°degree celsius . The concentration and temperature test ranges were maintained between 0-0.6% by volume and 25-50 degree celsius . investigated the effects of temperature and nanoparticle concentration on the temperature related conductivity ratio of hybrid nano-fluids using f-MWCNTs-$Fe_3O_4$/EG hybrid nano-fluids through both experiments and numerical analyses. They used a temperature and concentration range of 0 to 2.3% by volume. [15]

Ramesh batakurki et al[12] experimented on the solar vapour absorption refrigeration, he checked for the performance of the refrigeration using ammonia refrigerant and water as an absorption here the pressure of the condenser, pressure of evaporator are determined and matching points are fixed(fig 4).

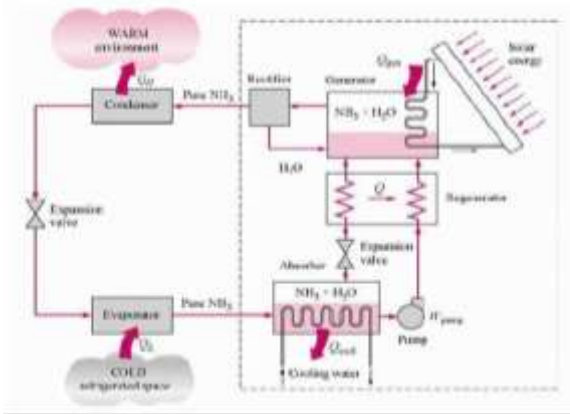
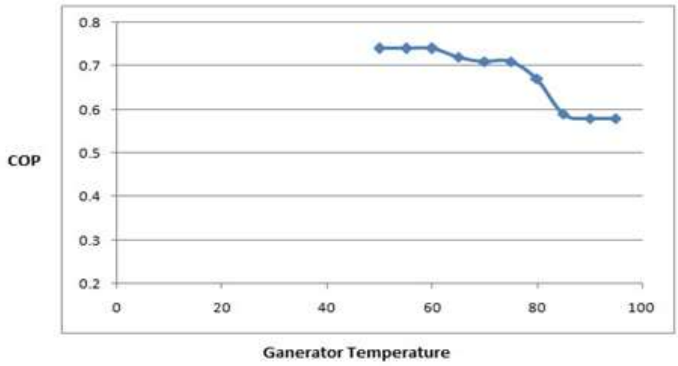
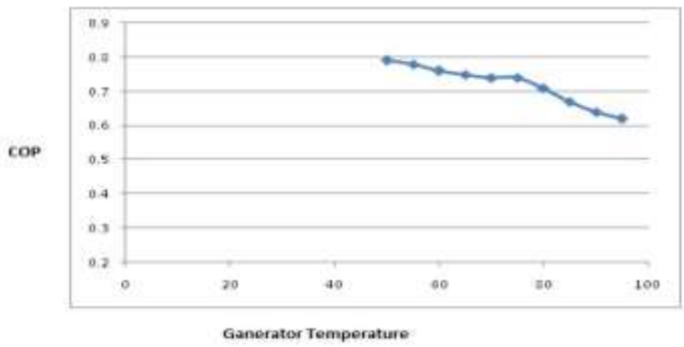



Fig 4 Mathematical model of the experiment



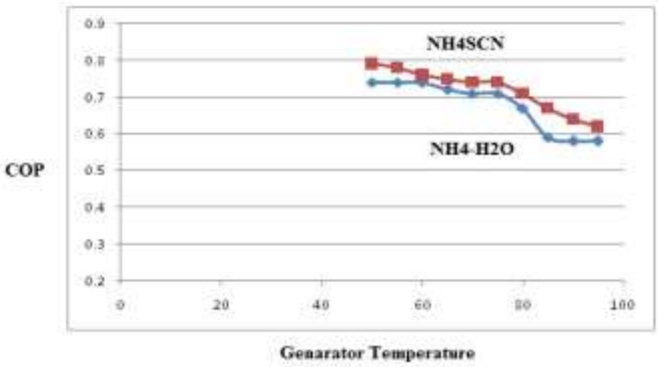

Graph 1: Variation of COP with different temperatures

This graph is plotted by using NH3-H20 as a refrigerant with different temperature at the unit which generates the heat.




Graph 2: Variation of COP using ammonium thiocyanate as refrigerant

The graph above depicts the COP of the variation with dissimilar temperature at hotness generating unit of $NH_4SCN$ as refrigerant, which provides better COP value when compared to ammonium solution [12].




Graph 3: Comparison between Ammonia water and ammonium thiocyanate

In this experiment it is concluded that there is a improvement in COP by using NHSCN as a refrigerant [12].

Ibrahim Atmaca et al[13]. developed computer program for the vapour system absorption which simulates numerous cycle operations and the parameters of energy. Solar powered, absorption system absorption system, using a H20–Libr solution the following diagram of a solo staged absorption cycle of refrigeration which uses Libr and H20 as working fluids. The Libr aqueous solution functions as an absorbent and water as refrigerant. The system includes the following like valves heat exchangers, piping and pumps. The system of photovoltaic also include tanks, solar collector, and heating. Absorption chillers uses the solar energy which will be gathered in the solar array collectors to drive the vapor out of the fluid solution. Vapour streams into condenser, heated fluid reverts to the absorber through the choke of absorption valve which closes the loop. Throttle valve upholds a pressure between the generator and the absorber. A huge quantity of thermal energy is lost by pumping the heated absorbent from the absorber and into the generator. A fluid/fluid heat exchanger that transfers the energy from it to a weaker solution that will be pumped to the generator which saves much of the energy. In the absorber the vapor is absorbed into a highly focused solution. The solution is debilitated by absorbing H20 vapor from the evaporator. Steam will be condensed in the condenser and flows to evaporator.

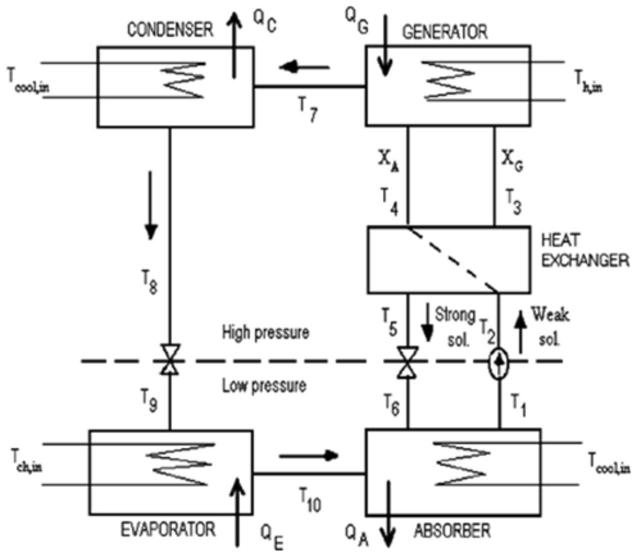



Fig 5.Schematic diagram of the absorption cooling system.

From this experiment it is concluded that the hot water inlet temperature disturbs some surface extent of the system components. Which increases the temperature reduces the surface area of the absorber and solution heat exchange, while the dimension of another component remain mainly same. It also demonstrates that absorption refrigeration system require a high performance solar collector For the solar vapour refrigeration to perform effectively the solar absorption cooling system which will be highly effective is required[13].

***Ammonia-water system***

Ammonia - Water has been widely used since the origination of the vapour system absorption refrigeration. Both NH3 and H20 are extremely steady over a wide-ranging temperature and range pf the pressure. Latent heat of vaporization of ammonia is very high, which is mainly required for the system to operate efficiently. Because the freezing point of ammonia is -77°C which is mainly used in low temperature applications. However, because both NH3 and H20 are unstable, the cycle mainly requires rectifier which removes the H20 that evaporate with the ammonia. Water would be gathered in the evaporator without a rectifier, reducing system performance. Other drawbacks due to high pressure, corrosive and toxicity on copper and copper alloys. Ammonia mixtures are hardly flammable, nonetheless it will be explosive at high ammonia concentrations ranging from 15.5 to 27%.

## Literature review

V. K. Bajpai et al[1]. designed and investigated an eco-friendly vapour absorption refrigeration system using R 717 ($NH_3$) of unit capacity and water as absorbent. the concept of this paper is extracted from the institutes solar panels installed on the roof. They created solar refrigeration system absorption type shown below [1].

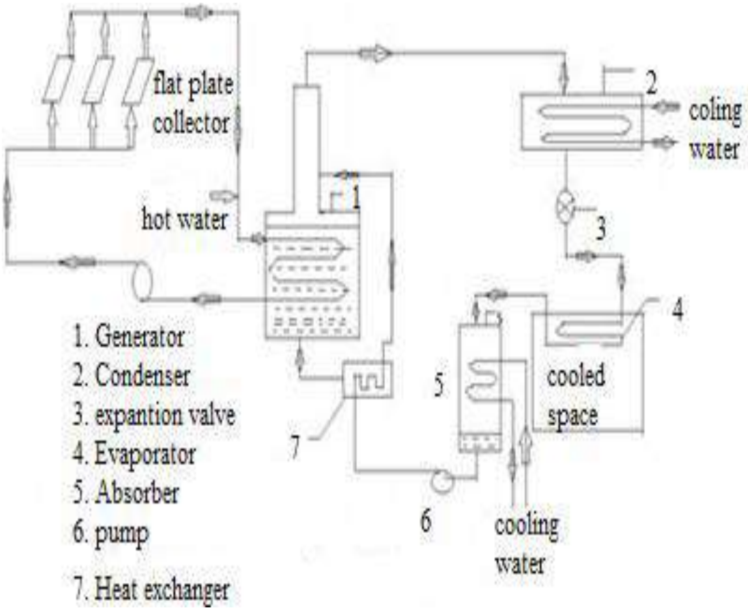



Fig 4 layout of Solar absorption refrigeration system

The input heat required to operate the 1TR absorption refrigeration system was calculated to be around 304.2 KJ/min. The hot water from the flat plate heater is used to power the generator. The performance coefficient is also calculated for this system. The results are obtained as:

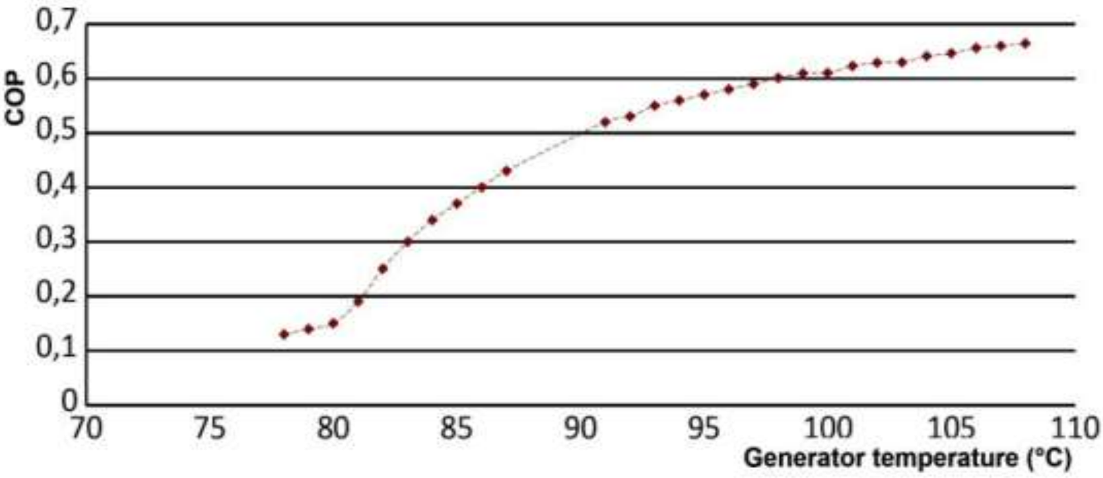
- Flow rate of cold water=3 Kg/min
- Pressure of the condenser: 10 bar
- Pressure of the Evaporator : 1 bar
- Heat required (generator) = 304.2 KJ/min
- Required Area of the solar collectors = 24 sq.mt i.e., 4 plates of 3×2 m2 is used.
- Outlet water temperature from solar heater = 84℃
- Coefficient of performance of refrigerating unit = 0.69

Overall cop of the system= 0.58

From above results, the feasibility of the solar powered absorption type refrigeration system [1].

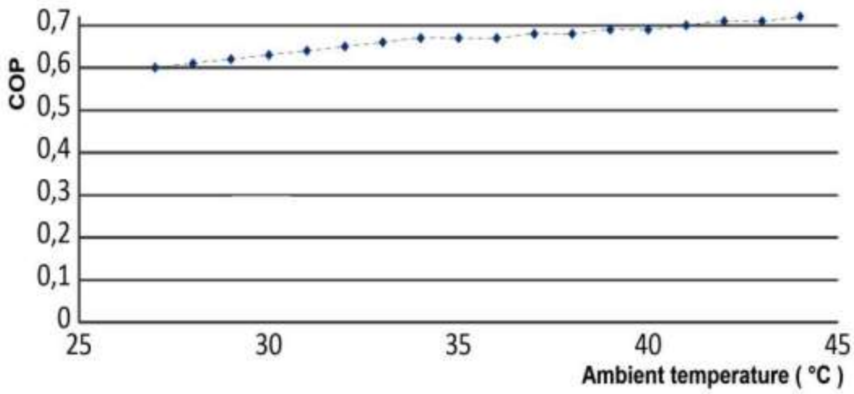
The absorption refrigeration system was reported by Ashwin Philip Kurian et al. The absorption type refrigeration system serves a load of 1.2 kW while operating at a lower temperature of -4 ℃, required approximately 2.4 kW of heat input to generator and bubble pump. When heat output at the absorber and condenser was nearer to 55 ℃, the system requires vacuum tube of high performance solar thermal collector with COP nearly equals to 0.5and 6.4m2 area of absorber . This was to accommodate fruit of 500kg and vegetables in a 12m2 floor area. It was outfitted with a 6-kWh ice battery bank. However, at nearly 190℃,for the generation purpose this required high temperature and thermal input of bubble pumping [6]

N. Hatraf et al [7]. investigated the impact of external and internal factors. solar Lithium Bromide operating conditions chiller by absorption [7].




Graph 2 Effect on COP based on ambient temperature

The COP is affected by the temperature of the generator, as shown in graph 1 The higher the rise of the boiling temperature, the Water vapour separation is simple and quick. As a result, we improve the effectiveness however, the generator inlet absorption chiller Temperature cannot be raised excessively because of the result of the Li-Br crystallisation [7].




Graph 3 Effect of ambient temperature on COP

According to the outcomes, the author concluded that Lithium bromide water absorption chiller is more suitable than other chillers for the same capacity, because it does not depend on multiple factors if we use chilled water condenser, whereas air cooling system is affected by temperature which is ambient and which fluctuates throughout the day. By taking crystallisation of the LiBr into account, the temperature of a generator is a most important factor in designing an effective absorption chillers [7].

T. Srinivas and colleagues created a cogeneration plant by combining a cooling system of kalina with a vapour absorption refrigeration system. This theoretical thermodynamic evaluation employs an $NH_3+H_2O$ mixture as the working fluid. The plant can be operated using low temperature heat recovery (150 ℃-200℃) from, solar collectors, engine exhaust gas or similar. To meet the changeable demand, a amount of cooling or power is provided by controlling facility. power and cooling cycles where flow control is located, the liquid refrigerant absorbs evaporator surroundings absorb more heat in this proposed plant. To develop efficient working conditions, the plant characteristics are calculated with changes in, separator vapour fraction, separator temperature, mass split ratio and turbine concentration. To run nearly full load of coupled plant at, around 80% to 100% varies the power of mass split ratio. The vapour fraction and temperature of the separator are optimised at 45% and 150℃, respectively. For optimal power and cooling, the turbine concentration should be kept above 0.85. The power splits ratio at 80%, the maximum cycle and plant EUF are approximately 0.15 and 0.06, respectively. At these conditions, the specific cooling and specific power are 72 kW/kg and 62 kW/kg, respectively[8].

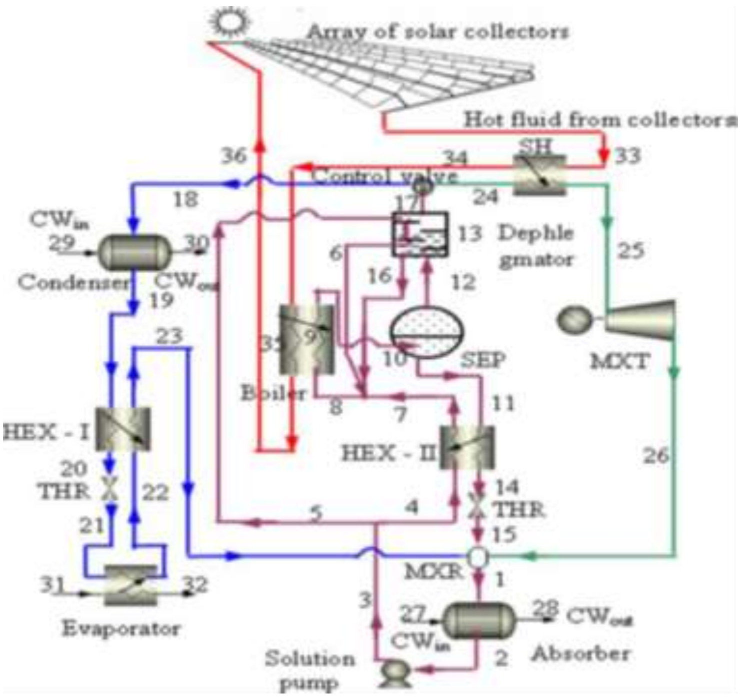



**Fig 2.4** Cogeneration Kalina cycle system with a vapor absorption refrigeration system

Lim Chin Haw et al [9] inspected an air conditioning system, which is currently the most applicable device in most buildings. Most small office buildings today the use of cooling technologies, which have a high power consumption, highest load demand for electricity. In general use refrigerants with variety of undesirable environmental impacts. Due to higher cost of energy, resources of fossil fuel depletion, influences in environmental pollution. As a result, subordinate renewable energy sources are used, such by means of using solar energy in refrigeration cooling. The brief detail was presented in the referred paper technical overview as well as economic feasibility of air conditioning using solar energy system. An absorption chiller with a capacity of 23 kW and C.O.P of 0.7 is used in this study. In small offices, they discovered that solar supported air-cooling system with a small absorption cooler works well. It saves a lot of energy and has a lower environmental impact, particularly in terms of CO2 removal. To maximise the use of solar thermal energy by consuming it without short of restricting only for power the absorption cooler and also to offer warm water to the handlers. Together of these applications have potential to increase the economic viability of a solar powered air acclimatizing system. In spite of a solar assisted air conditioning system requires a significant capital investment, the 8-year payback period makes this expertise a practical outlay aimed at individual client too the creator of a slight office block.

According to Siddiqui et al[16] he described the various methods of solar cooling done based on experimental and numerical analysis. The paper presented that the solar cooling is more efficient than PV cooling. The paper study focused on the type of refrigerant used, the working of different chillers and the how they have performed based on the working system by comparing to most commonly used refrigerant ammonia-water and lithium bromide. The researcher came to a conclusion that it is possible to reduce the CO2 emission by using solar absorption cooling systems, the cost associated with it should be reduced substantially. In this system generator temperature range is limited to 10-30°C. Generator temperature is defined as the difference between maximum and minimum temperature at the generator and are controlled by solar collector the is large decrease in in COP when they areoperating away from the design point temperature. Large tank volume is required because of insufficient temperature range, most widely used medium for solar cooling applications.

***Thermodynamic analysis***

In this system compressor as shown in the figure. The refrigerant flows to the condenser from a generator as well as compressed in the compressor and return to the generator adding the heat to solution. Though it is cooled into liquid. Later it goes to heat exchanger for removing the heat and then to the throttle valve. Lastly, refrigerant will flow to the condenser. The compressor acts as a heat transformer, receiving heat from the generator. The heat transformer provides the heat to the solution. The temperature rise in the transformer will be very small- According to the first rule of thermodynamics, the total heat rejected to the environment equals the heat absorbed by the system:

Since the rise of temperature of heat exchanger is equivalent to the temperature difference created when air is squeezed by a compressor, it flows to the generator and heat transfer takes place and has a comparatively high back to the generator. On the other hand, the heat generated and condensed both decrease.

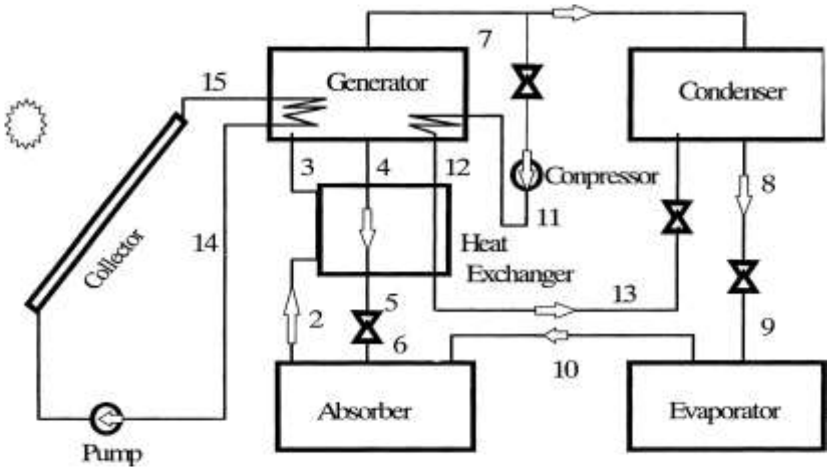



**Fig. 6.** Schematic representation for the new refrigeration cycle.

According to the second law of thermodynamics, all the high-temperature vapour generated by the traditional cycle release the heat directly into the environment by the condenser, but in the new cycle, the high-temperature vapour does not do so. As a result, there is a smaller temperature difference between the environment and the heat transferring fluid. As a result, the irreversible loss is decreased, increasing the rate at which energy is used [17].

### *COP Affecting Parameters*

The evaporator temperature, condenser temperature, and condenser temperature all have an impact on COP. The better the COP, the evaporator temperature will be high and the condenser temperature will be low. A temperature increase of 1℃ in the evaporator or a temperature decrease by 10℃ will improve the COP in the condenser by 2% to 4%. Changing process temperature settings can be used to raise the evaporator temperature.

Installing a higher-rated evaporator with more heat transfer area. Which keeps the heat transfer surface unstained, which includes avoiding fouling and defrosting as needed. To raise the evaporator temperature, change the process temperature settings. Installing a more powerful evaporator with a larger heat transfer area. Maintaining the cleanness of the heat transfer surface, which includes avoiding fouling and defrosting as needed. The different types of compressor used can also affect the COP. The amount of refrigerant charged in the system. The system will consume more power when there is refrigerant leak in the system [11].

## Conclusion

All year round due to its geographical distribution throughout the country. Among refrigeration cycles which is driven by heat, the vapour absorption refrigeration system was considered suitable for the scenario's of rural India due to the high solar irradiance across India. Waste heat from photovoltaics and large amounts of biomass and agricultural waste can be used to meet heat needs without sunlight. Among the main working pairs available, NH3-H2O is believed to be more suitable for solar cooling storage due to its performance at higher coefficient. The machine uses environment friendly refrigerant H2O, which generally has no global warming potential. Since, the machine operates without a compressor, it significantly reduces noise emissions. The machine uses environmental friendly refrigerant H2O.

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