Review on Lithium-Bromide/Water Vapor Absorption Air-Conditioning System using Solar Energy

Hardik G Moliya
M.E. Student (Thermal Engineering)
Department of Mechanical Engineering
A.D. Patel Institute of Technology, New V.V. Nagar, Gujarat-388121

Abstract— This paper reviews past efforts in this field of solar operated air-conditioning systems using the absorption pair of lithium bromide/water. A number of attempts have been made by researchers to improve the performance of the solar air-conditioning system. Lithium-bromide/water system is more effective than any other pair of absorber-refrigerant. It is seen that the inlet temperature of generator is the most important parameter for optimize the design and fabrication of a solar operated air-conditioning system. While system design, collector choice and arrangement of system are other impacting factors for the system operation. The parabolic through collector is very effective for reach the sufficient generator temperature. In this paper we analyse double stage vapor absorption cycle is more effective than single stage absorption cycle. Solar energy applications in for domestic hot water, space heating and cooling have been considered very effective. The ultimate goal of this study in the long term would ideally be to reduce the consumption of electricity used for air-conditioning system.

Key words: Solar, Parabolic Trough Collector, Single-Double Stage Cycle

I. Introduction

Solar energy is the One of the most important source of energy. It is a inexhaustible(renewable) and environment friendly and not a result of using fuel or other hazard's products that leave residual waste such as a radioactive waste which results from using nuclear energy[6]. Absorption systems are the most effective applications of solar energy for air-conditioning and refrigeration as using solar energy to supply the system´s required heat, so the interest in this application is very beneficial; because need of cooling is high with high intensity of solar radiation and temperature, and the more high intensity radiation increase the temperature of the hot water out from the solar collector and has been supplied to the absorption system, hereby increasing the efficiency of the system, and because of the shiny climate of India throughout the year, it is very much possible to use absorption system using solar energy[1].

Researchers have shown very much Interest to studying the solar operated absorption cooling system, because of some key reasons of these system. Increasing conventional energy costs, fear of depletion of conventional energy sources and environmental problems all added to this interest beside the fact of energy being a cornerstone of civilization and criteria of development. An air-conditioning system using solar energy would generally be more effective and efficient, cost wise, if it will used to provide both heating and cooling requirements in the building it serves [3].

Various heating systems have been tested extensively utilizing solar energy, but solar operated air conditioning systems have received very little attention. Solar operated absorption cooling systems can used for both heating and cooling requirements in the building it serves. Lots of researchers have studied the solar absorption air conditioning system to make it economically and technically feasible. But still, much more researches in this area are needed. The solar energy is dependent on collector area, and is a diluted form of energy and is available for only a fraction of the day. Also, solar energy availability depends on several factors such as latitude and sky clearness [2].

A. Basic Principle

The collector receive energy from sun and it gives to generator in which strong solution comes from absorber with the help of mechanical pump here strong solution receive heat and water evaporate due to lower boiling point and water will goes to condenser and Li-Br goes to heat exchanger where it will again transfer heat to strong solution[5].

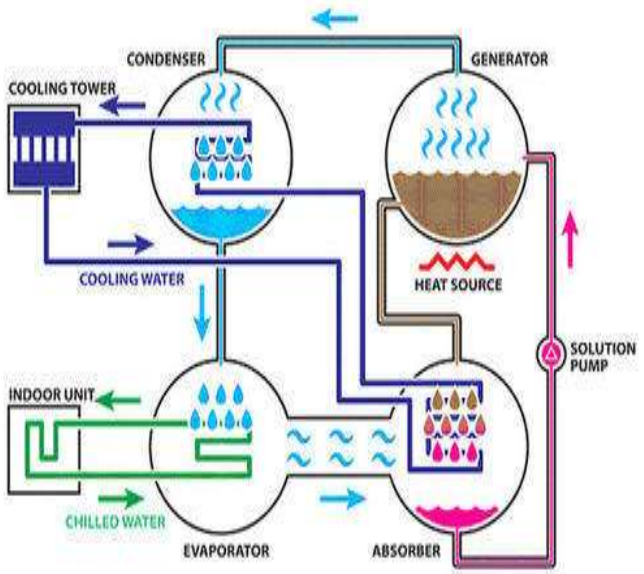

Fig. 1: Architecture

Water goes to condenser here first remove sensible heat up to temperature 40℃ and than transfer latent heat at 40℃ so the water phase change from vapor to liquid. Then it expand through expansion valve so its pressure become lower. In evaporator refrigerant again change the phase due to taking heat from atmosphere.

Then in absorber Li-Br absorb the water from evaporator so the water dissolved quantity increase so it will become strong solution again, and temperature of solution goes down because the absorption process is exothermic reaction so heat has to be removed then it goes through liquid-liquid H.E it will improve performance of system. Then again cycle repeat[7].

B. The most commonly used refrigerant-absorbent pairs in commercial systems

1) Water-Lithium Bromide (H_2O-Li-Br) system for above 0^oC applications such as air conditioning. Here water is the refrigerant and lithium bromide is the absorbent.
2) Ammonia-Water (NH_3-H_2O) system for refrigeration applications with ammonia as refrigerant and water as absorbent.

Of late efforts are being made to develop other refrigerant-absorbent systems using both natural and synthetic refrigerants to overcome some of the limitations of (H_2O-Li-Br) and (NH_3-H_2O) systems.

Currently, large water-lithium bromide (H_2O-Li-Br) systems are extensively used in air conditioning applications, whereas large ammonia-water (NH_3-H_2O) systems are used in refrigeration applications, while small ammonia-water systems with a third inert gas are used in a pump less form in small domestic refrigerators (triple fluid vapor absorption systems)

II. LITERATURE REVIEW

These are the research reviews subjected to vapor absorption system using solar energy. A review from the available literature the vapour absorption technologies are presented here. Study of refrigerant & absorption pair and different configuration of vapour absorption cycle is the primary objective of this literature review.

Z.F.Li, K.Sumathy [1] (1999) Represented past efforts in the field of solar operated air-conditioning systems with the absorption pair of lithium bromide and water. Experimental results show that the generator inlet temperature is the most important parameter in design and fabrication of a solar operated air-conditioning system. While collector choice, system design and arrangement are other influencing factors for the system operation.

The main advantages of solar absorption air-conditioning system has provide the sunshine and the need for refrigeration reach maximum level in the same season. Although solar powered air-conditioning systems are readily available in commercial sizes, existing solar cooling systems are not competitive with conventional electricity-driven air-conditioning systems because of their high first cost. Several technical problems associated with the design and development of absorption chillers based on continuous cycles have been successively resolved, and new trends gradually developed towards the redesign of the chiller generator for operation at temperatures lower than 100℃.

Of the two main technologies of solar cooling systems discussed in this paper, the focus is placed on the cooling technology rather than on the thermal technology, which places an important factor in increasing the COP of the air-conditioning systems. It is shown that although the single-effect system with refrigerant storage has the advantage of accumulating refrigerant during the hours of high solar isolation, the double-effect convertible system has a higher overall COP. And the advantage of two-stage system has to the lowering the generator temperature, which rectify the system performance and also the use of conventional flat-plate collectors to achieve high COP. The researcher carried out many other achievements, there should improvements made to the solar operated air-conditioning systems in order to compete with the conventional air-conditioning systems.

V Mittal et al. (2005)[2] This paper will help many researchers working in vapour absorption area and provide them with fundamental knowledge on absorption systems, and a detailed review on the past efforts in the field of absorption cooling systems using solar energy with the absorption pair of lithium-bromide and water. This knowledge will help them to start the parametric study in order to investigate the influence of key parameters on the overall system performance.

Here, the technical and economic analysis of single effect solar absorption system with pair Li-Br/water was done. This analysis was accomplished for a typical office building in Tehran. The plant provided cooling for a floor area of $280m^2$. Furthermore, the plant included an auxiliary heating system and its capacity was about 13KW. The highest environmental benefits is the most important advantage of this system. The other advantage is that we utilize the highest total energy saving.

It was shown that the solar cooling effect for mentioned office building was 64.3% and solar heat pipe collector area was $45m^2$ which is optimized area. In this plant utilizes 16 collectors which everyone compromises 30 tubes. Finally, 13 year was payback time of this plant was estimated.

A.M.Abu-zour, S.B.Riffat [3] (2006) A review of various cooling cycles and conclude work carried out on solar-operated air-conditioning systems in this paper. This section presents a concise explanation of each cycle compare with the other methods. The issues associated with various solar-operating cooling systems are also discussed like technical, environmental and economic.

Various technologies for solar operated air-conditioning system have been described. In comparison with conventional vapour-compression systems, these systems usually have a higher initial cost, and it is economic barrier, instead of technical difficulties, which has limited the emergence of these technologies. The collector is normally the most expensive component of a solar-operated system, it should be cost effective to use them for more than one purpose, the Collector is used for water heating system in a winter, and it can be used to operate an air-conditioning system during the summer.

It is more practical to base a comparison of the COP of the solar operating system with a vapour compression systems on the base of work output. The reason behind the high values of coefficient of performance for vapour compression cycles is then clear, there is no heat input required and heat is low greed energy in a vapour compression system used electricity so COP higher.

The uses of combine cooling cycle can be an effective solution to overcome the limitation of various cooling cycle, one of the example the low COP. The high initial cost of solar system would fall as mass production technique involve with market.

Muhammad Ali, PE (2011) [4] Solar cooling system is used to provide comfort cooling and to provide refrigeration for food and medicine. This systems are particularly applicable to large applications (e.g. commercial buildings) that have very high cooling loads for large periods of the year. Peak cooling demand of the building and the availability of solar radiation is in phase and matches perfectly. This will make solar cooling of the building a renewable energy source and green solution. Lithium bromide (Li-Br)-water absorption unit is more suitable for solar application since their working (generator) temperature is lower and thus more readily sustainable with lower-cost solar collector.

Air-conditioning system can provide full load of building using by solar absorption system. The excess heating available in the day time can be stored to utilize in the evening, night and early next morning to provide heating to generator and get cooling at the time when solar energy not available.

Mainly The payback period of VAAC using solar energy depend mainly on solar radiation available, rating of electricity and peak charge. The pay back of these system will be very shorter in future because of expected high fuel and electricity charge. Also solar cooling will become a cheaper solution with effective research and large production of solar cooling equipment. The refrigerant in future will also make VAAC system using solar energy an attractive options. Thermal energy storage tank can provide 24*7 cooling using solar energy it is an integrated solution for full day.

H.E.Zinian [5] (2000) A solar-operated air-conditioning system using absorption principle with 100 kilo-Watt cooling capacity has been successfully designed and fabricated in Shandong Province, China. The system are consist of lithium-bromide absorption chillers, heat-pipe evacuated tubular collectors, water storage tanks, circulating pump, fan-coil unit, cooling tower, control device and auxiliary oil-burned boiler. This paper presents design characteristic and measuring performance of the system, which involves a multi-function in summer space cooling, in winter space heating and in other season's water heating for domestic purpose. Thermal efficiency of the collectors respectively for space cooling 40%, for space heating near about 35% and for domestic water heating above 50%. Total cooling efficiency is 20% around for the entire system.

The vapour absorption air-conditioning system using solar energy has been used for space cooling, space heating and water heating for domestic purpose. This multi-functional system explore economic benefit of the system. Measured thermal efficiency of the solar collectors are over for space cooling 40%, for space heating 35% and for domestic water heating near about 50%. It indicate that heat-pipe evacuated tubular collector array is suitable for application at higher operating temperature and lower atmospheric temperature.

In the early morning in summer as the smaller storage tank is specially adopted, hot water temperature can be raised up to 88℃, as well as to in the early morning in winter its 55℃. The chilled-water storage tank is useful for lowering heat loss because temperature difference between atmosphere and chilled-water is much smaller than that between ambient and hot water. Measured COP of the chiller is approximate 0.70. Total cooling efficiency of the entire system is around 20% under local condition.

R.Fathi et al. [6] (2001) This paper is presenting the variations of COP and the heat-transfer rate, with different temperature of the cycle, the obtained value of single-stage heat exchanger is compared with an improved configuration using double-stage heat exchanger.

In this paper, we have developed a method of calculation that is based on simple analytic data which relates the thermodynamic variable of the lithium-bromide/water couple. Thus, we are able to explain easily the thermodynamic mixture state of lithium-bromide/water pair, in different steps of the absorption cycle without using chart data or diagram table. The simulation result has disclose that there is a temperature limit "under/over" of which the cycle can't working. Moreover, the temperature of the cold source has an effect on the threshold of functioning of the cycle. The COP reached maximum value for mean temperature 20 °C or 25 °C and evaporator temperature 10°C. The use of a double line heat exchanger is to recover a part of the condenser load improve by the COP of both cycles by about 4 %

Actually in this paper develop new approaches based on thermodynamic irreversible model. The application of non-equilibrium phenomenological theory of mass and heat transfer, with special emphasis few case including physical binary gas liquid interaction in non-ideal mixtures is the most important key point in this study.

Amir falaharkar, M.Khalaji Assadi [7] (2011) The aim of this study is to analyze the solar single effect lithium bromide/water absorption cooling systems in a typical commercial building in Tehran. The sun energy is absorbed by heat pipes and stored in an insulated storage tank. This system has been designed to supply the cooling load of 10 tons of refrigerant (35.17KW).

According to Tehran climate and its specification the Results demonstrate that the building with an optimized design of solar collector's heat pipe, up to 2400 m^3/year saving of natural gas can be reached by absorption cooling system using solar energy. 16 collectors are required to use for achieving this purpose which every collector has 30 tubes with total area of absorber 45 m^2 which is the optimized collector area for this plant in Tehran. According to these replacement the investment payback period would be 13 years which would be much shorter than the payback time of a solar cooling system combined with conventional all air systems.

In this study the economic and technical analysis for single effect Lithium-bromide/water solar absorption system was done. The analysis has accomplished for a typical commercial building in Tehran. The plant provided air conditioning for a floor space of 280m^2. Furthermore, the plant has an auxiliary fossil system and its capacity has about 13KW. The most important advantage of this system is that it offers the highest environmental friendly benefit. The other merit is that we utilize the highest total energy saving.

It has clearly shown that the solar cooling fraction for mentioned commercial building has 64.3% and the optimum area of solar heat pipe collector has 45m^2. It means that this plant utilizes 16 collector which every collector has 30 tubes. Finally, the payback period of this plant has been estimated about 13 year.

V.K.Bajpai [8] (2012) The focus of this paper is to study and design of an vapour absorption refrigeration system of unit capacity using ammonia/water as the working pairs. The system is designed and teste for various operating condition using hot water as heat source. This paper present, performances of the fabricated system is shown with respect to various operating condition related to heat source, condenser, absorber and evaporator temperatures. The general idea of this paper is derive from the solar heating panel installed on the hostel roof of the institute. The whole unit was installed for about an investments of Rs. 1.70 Caror. But the ironies are that, this solar heating unit remains idle in the summer month. Also the solar potentials are at maximum in the summer.

As calculated earlier, the heat input required to run the 1 TR vapour refrigeration unit, for the operating conditions designed, is about 304.2 KJ/min. This heat in the generator is supply by the hot water coming from the solar flat plate water heater. For this system the coefficient of performances is also calculate. The results can be summarized as:

- Mass flow rate of water = 3 Kg/min
- Designed operating condition:
- Condenser pressure: 10 bar
- Evaporator pressure: 1 bar
- Heat input require (at generator) = 304.2 KJ/min
- Area of the solar collector require = 24 square meter
- i.e. 4 plates of 3×2 m^2can be used.
- Output temp of water from solar heater = 84℃
- COP of refrigerating unit = 0.69
- COP of the whole system = 0.58

In light of the above result, the feasibility of the solar operating vapour absorption refrigeration system was reasonably proved. The COP values as calculated by us are on a little higher side than the actual COP but because we have assumed ideal process in heat exchange etc., this obliquity can be understood. Hence, a solar water heating unit can be usefully employed for water cooling purpose. In the month of summer, when the solar heating unit is close and even the solar potential is quite higher, the unit can be used for refrigeration's. This will actually justify the huge investment made on these unit, and the energy source will not remain idle during its peak producing time.

Jhalak Raj Adhikari, Badri Aryal et al. [9] (2012) The paper describe the need and importance of solar operated cooling system that can play a very important role in attenuating energy crisis by the use of solar energy. The study investigated and evaluated the feasibility of an absorption air-conditioning unit using solar energy. The system designed here function with the principle of absorption refrigeration having Lithium Bromide/water pair.

A design and simulation of absorption air cooling system using solar energy as source of energy, for an office building has been done and the system performance was analysed parametrically by using Energy Equation Solver. It appears that best performance in terms of COP should be obtained when we work with lower generator temperature range and low generator heating. The cooling load for this systems are obtain as 5 kW. The COP of the System is 0.77. Solar collector area to conduct system is 8m^2. On the increase of mass flow rate of refrigerants, an ultimate cooling effects increase, but COP decrease. This vapour absorption air conditioning system using solar energy is an alternative to conventional VCR system. Here, Li-Br was selected as absorbent for cooling purpose and H2O as refrigerants. The ultimate goal is for the long term would ideally be to reduce the consumptions of electricity using for refrigeration's and air conditionings.

Dr.A.S.Dawood, H.A.Yousif [10] (2012) This study deals with the optimised design of an absorption air-cooling system with cooling capacity of 2 ton refrigeration's operated by solar energy and using Water as a refrigerants and Li-Br as absorbent. This systems use water for cooling the absorber, condenser and for heat transfer in the evaporator. A mathematical models are built to simulate a solar collector system and absorption system, in addition to design flat plate solar collector, f-chart method is used to find the optimised require solar collector area to air-condition a space in the establishment with eight hour per working day.

The coefficient of performance (COP) has been taken as a measurement to find the optimum internal operation condition, by examining the performance of absorption system with vary temperature to the generator, absorber, condenser, evaporator and effectiveness of a solution heat exchanger to obtain the optimised value of this operation condition and also obtain maximum value of the COP. The results show that the collector's area was a large effect on the actual useful heat gain and auxiliary heat to the system, and a collector area 26 m^2 is enough to operate vapour absorption system more than eight hours by using a water storage tank with a capacity of 1.5 m^3 and depend on weather data of Mosul city. The result also shown that the generator temperature had a great effect on the absorption and solar collector system.

This research was done to study the combine system consisting of a flat plate solar collector system with a single effect lithium bromide absorption cooling system. After getting the result it has been conclude the following:

1) Getting a large amount of thermal energy provided by a solar in the case of use of double cover flat plate solar collector instead of one cover.
2) Area of a solar collector has a greatly effect on the amount of heat gain from solar collectors, as well as the amount of heat supply by auxiliary heater.
3) Solar collector area 26m2 is sufficient to operate absorption system more than eight hour by using water storage tank with a capacity of 1500L and depending on weather data of Mosul city.
4) The generator temperature (80°C) gives the minimum number of solar collector unit, this optimised generator temperature corresponds to generator temperature giving the maximum COP, when the condenser temperature is 40°C, the absorber temperature is 35°C and the evaporator temperature equals 12°C.
5) The generator temperature has a greatly effect on the absorption system COP.
6) The system COP increasing by decreasing the condenser and evaporator temperature.
7) The system COP increasing by increasing the evaporator temperatures.

8) The solution heat exchangers which are place between the generator and absorber increase the system COP significantly.
9) A parallel connect between the absorber and the condenser results in the decrease of the condenser area.

III. Conclusion

The conclusion of this literature study is following:

1) LiBr/Water pair is more effective for air-conditioning system and ammonia-water pair is more suitable for refrigeration system.
2) Double-effect system has 4% more efficiency than single-effect system.
3) Copper material is more effective than mild steel and stainless steel for vapor absorption system.
4) Cost of copper heat exchanger is lower than steel heat exchanger.
5) Generator temperature is most critical temperature for design and fabrication of vapor absorption system.
6) COP of vapor absorption system is depend on Generator temperature of system.
7) VCR system has more initial cost than VAR system but COP of VCR is more than VAR.

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