IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 2 Ver. II (Mar. - Apr. 2016), PP 09-13
www.iosrjournals.org

Solar Vapour Absorption Cooling System Using parabolic dish Collector

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Abstract:*In view of depletion of the conventional energy resources like coal, petroleum etc., it is necessary to utilize renewable energy resources to meet the world energy demand. There is a need to develop more strategies for trapping of these non-conventional energy sources. Out of these resources one of the best and effective sources of energy is the solar energy. In India many solar devices are developed and in particular, solar water heating systems with flat plate collector are extensively being used in commercial as well as domestic areas. The usage of solar water heating system is high in seasons other than summer. Although the solar energy collection efficiency is enormous in summer, the corresponding utilization rate is low. Therefore in the present work an attempt has been made to produce the refrigeration effect by obtaining the energy from one single flat plate collector, with the help of vapor absorption refrigeration technique. In this way a commercial single flat plate water heating system can be used for heating purpose in winter and rainy seasons and cooling effect during summer.*

Keywords:*Flat plate collector, solar heating system, Vapour absorption refrigeration, COP, Ammonia-water, Low cost*

I. Introduction

Solar energy is a very large inexhaustible source of energy. The power from the sun intercepted by the earth is approx. 1.8 × 1011 MW, which are many thousands of time larger than the present consumption rate on the earth of all commercial energy sources. Thus in principle solar energy could supply all the present and future energy needs of the world on continuing basis. This makes it one of the most promising of the unconventional energy sources. Solar energy can also be used for cooling buildings (generally known as air-conditioning) or for refrigeration required for preserving food. Solar cooling appears to be an attractive proposition due to the fact that when the cooling demand is more, the sunshine is strongest. This, along with the necessity for providing thermal comfort for people in hot areas of the world and for providing food preservation facilities, may be the motivating factor in continuing research and development in the field of solar cooling systems. Out of the various solar air conditioning alternatives, the absorption system appears to be one of the most promising methods. Chinnappa [1] developed a simplified approximate expression for the theoretical coefficient of performance of the ammonia-water vapour absorption refrigeration system, and also expressions are developed for the theoretical coefficient of performance of the ammonia-lithium nitrate system suitable for use with the corresponding data charts. Tyagi [2] conducted several experimental studies with a large number of promising binary mixtures, for use in vapour absorption refrigeration and air conditioning systems, and concluded that one of the mixtures Ammonia and Water is suitable where low grade thermal energy such as solar energy and waste heat is available at temperatures between 100 and 120°C. A systematic investigation is made of the two-stage vapour absorption refrigeration system employing the refrigerant absorbent combinations of NH3---H2O and NH3---LiNO3. The effect of operating variables such as generator temperature, evaporator temperature, absorber temperature and condenser temperature on the coefficient of performance (COP), heat transfer rates and relative circulation have been studied for both single-stage and two-stage absorption refrigeration systems [3]. Economic analyses of some sources of energy, such as biogas, liquefied petroleum gas, ordinary flat plate and evacuated tubular collectors, have been carried out for operating absorption cycles with and without heat recovery absorber. For the set of operating conditions under study, the cost is reduced by about 25% in the H2O---NH3 cycle and by about 30% in the NaSCN and LiNO3---ammonia cycles [4]. A solar cooling machine has been built for demonstration purposes [5]. The main part of the device is an absorber/ desorber unit which is mounted inside a concentrating solar collector. The working pair consists of NH3 used as the refrigerant and SrCl2 used as the absorbing medium. Performance of the solar refrigeration unit was measured in a field test. Francisco et al. [6] developed and tested a prototype of a water–ammonia absorption system designed for solar-powered refrigeration in small rural operations. The equipment has been designed to operate with a concentrating solar power system to obtain the required temperatures. Overall, the test results showed unsatisfactory operation of the equipment having low efficiency. The usage possibility of ejector-absorption cooling systems (EACSs) in Turkey using meteorological data has been investigated [7]. It is shown that the heat-gain factor (HGF) varies in the range from 1.34 to 2.85 for all the seasons in the selected cities. According to the results obtained, it is sufficient to have a collector surface-area of 4 m2 with high-performance refrigeration all over of Turkey. Velumurugan et al. [8] described a detailed description of a new solar-based refrigeration system using three fluid ammonia-hydrogen/ water (NH3-H2/H2O) vapour absorption system. This technique uses solar energy to produce cold air and does not pollute the environment. The system cooling capacities were found to be between 100 and180 W with a COP between 0.09 and 0.15. NimaiMukhopadhyay and SomeshwarChowdhury [9] studied theoretical modeling of solar-assisted cascade refrigeration system in cold storage. The system consists of electricity-driven vapour compression refrigeration system and solar-driven vapour absorption refrigeration system. The vapour compression refrigeration system is connected in series with vapour absorption refrigeration system. The results shows higher COP as compared with the conventional vapour compression refrigeration system. COP of this type refrigeration system increases as sunlight becomes intense. Power consumption of the cascade refrigeration system is 50% lower than that of the conventional vapour compression refrigeration (CVCS) in the cooling mode. Although, considerable work on solar cooling systems has been done in the last four decades, due to its complexity, both in concept and in construction, the utilization and commercialization of solar cooling is not as widespread as other solar energy applications like solar water heating and solar space heating. In the present paper, an attempt is made to estimate the cooling effect with solar vapour absorption system using commercial 100 litres solar water heating flat plate collector device.

2. Experimental

2.1 Experimental Set-Up

The experimental set up consists of mainly two circuits as shown in Fig.1.

1. Solar water heating system circuit
2. Vapour absorption refrigeration circuit

2.1.1Solar water heating system circuit

It consists of an absorber plate on which the solar radiation falls after coming through two transparent covers of 4 mm thickness [made of glass]. The space between the covers is 1.5 cm. The absorbed radiation is partly transferred to a liquid flowing through tubes which are fixed to the absorber plate or are integral with it. This energy transfer is the useful heat gain. The remaining part of the radiation absorbed in the absorber plate is lost by convection and re-radiation in the surroundings from the top surface and by conduction through the back and edges. The transparent covers help in reducing the losses by convection and re-radiation in the surroundings from the top surface and by conduction through the back and edges. A liquid flat plate collector is usually held tilted in a fixed position on a supporting structure facing south if located in the northern hemisphere. The absorber plate is usually made from a metal sheet of thickness 1 mm while the tubes are with diameter of 15 mm. They are soldered, brazed/welded or pressure bonded to the bottom of the absorber plate, with pitch of 12 cm. The metal most commonly used for absorber plates and tubes is copper. The header pipes which lead the water in and out of the collector and distribute it to the tubes are made of the same metal as the tubes and are of slightly large diameters. The bottom and sides are insulated by glass wool with a covering of Al foil and has a thickness of 2.5 cm. The whole assembly is contained within a box which is tilted at a suitable angle.

2.1.2 Vapour absorption refrigeration circuit

The aqua-ammonia cooling system consists of the components: generator, absorber, evaporator, condenser and solution heat exchanger. Generator is nothing but a cylinder made up of MS material with a diameter of 300 mm and a length of 400 mm. inside the generator, a hollow helical coil is provided with MS pipe of 12.5 mm diameter. The outlet of refrigerant vapour from generator is connected to the condenser. Condenser is made up of 12.5 mm diameter MS pipe which is in coiled shape. The other end of the condenser is connected to the receiver tank. A receiver tank is nothing but a small cylinder of 50 mm diameter and 100 mm length which is made up of MS. Capillary tube is a pipe of small diameter of about 6 mm which connects the receiver tank and evaporator. Evaporator is a made up of 12.5 mm diameter MS pipe which is wounded in coil shape. The evaporator is located in a box which contains water. The refrigeration effect is produced inside the box. Capillary tube is connected to the inlet of the evaporator. The outlet of the evaporator is connected to the absorber. Absorber is a cylinder which is made up of MS with 100 mm in diameter and 300 mm in length. . It also has a provision to pour aqua ammonia solution which is later closed with a valve after filling the absorber. The outlet of the absorber is connected to the pump. The absorber is fully closed without any leakage. The pump lifts the solution from absorber to the generator. The pump is a fractional HP pump.

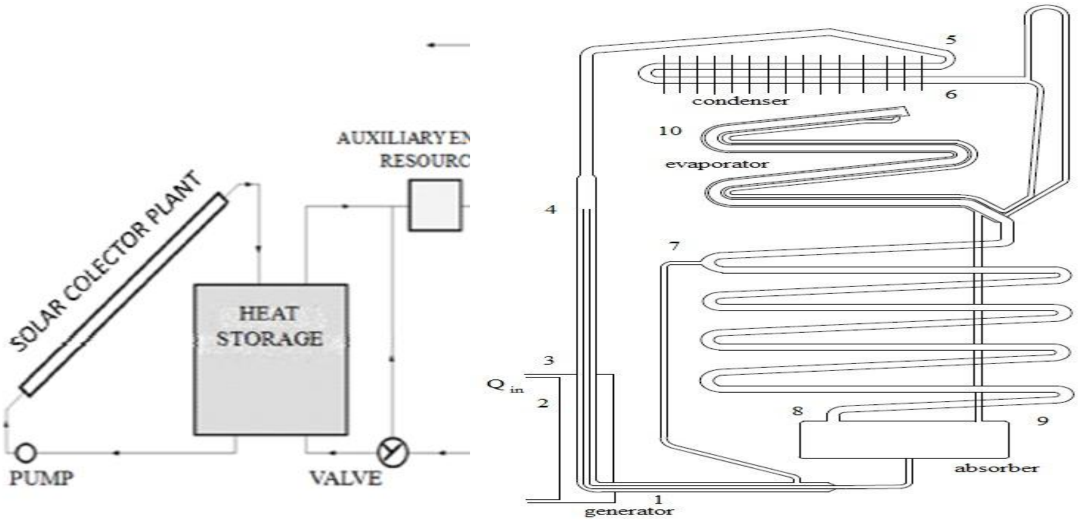

Fig.1 (a) Experimental set-up of Solar Cooling System

Fig.1 (b) Experimental set-up of Solar cooling System

3. Experimentation

3.1 Hot Water Circuit

First the available cold water is filled in the entire circuit of collecting tank, solar panel's riser pipes, header pipes & generator coils. Then the entire system is placed in open atmosphere to receive solar radiation. The radiation received by the absorber plate is transferred to the water in the riser pipes. As a result the water gets heated and the density decreases. As the hot water is less dense than cold water it automatically rises up and enters the collecting tank. The relatively cold water from collecting tank replaces the hot water in the riser pipes and the procedure repeats. The collected hot water then circulates in the coil placed in the generator where the hot water gives off its heat to the refrigerant. So in the hot water circuit the water receives heat in the solar panel and gives off the heat in the generator.

3.2 Refrigerant Circuit

The refrigerant gets separated from the aqua ammonia solution in the generator by absorbing the heat from the hot water in the generator coil. The ammonia after getting vaporized flows through the circuit and enters the condenser. In the condenser the refrigerant Vapour gives off its heat to the surrounding air and gets converted into liquid ammonia. So the refrigerant gives off its latent heat in the condenser. The liquid refrigerant then enters the capillary tube where the pressure drops to the evaporator pressure. The low pressure low temperature liquid refrigerant then enters the evaporator receives heat and produces the refrigerating effecting in the evaporator cabinet. The refrigerant gets converted into Vapour after receiving the heat. The Vapour refrigerant is absorbed by the water present in the absorber. This is due to the chemical affinity of the water towards ammonia. This is the motive force for the refrigerant. In the absorber the ammonia Vapour mixes with water and results in aqua ammonia solution. This solution is pumped to the generator pressure by a fractional HP pump. In the generator the ammonia gets vaporizes and separates from the solution. If any amount of ammonia remains in the solution it is sent back to the absorber through capillary tube. Thus the cycle repeats. After the system is reached to steady state the following readings are taken

1. Collecting tank water outlet temperature
2. Temperature of the refrigerant before evaporator
3. Temperature of the refrigerant after evaporator

II. Results And Discussion

The experiment test trails are conducted about five hours per day for 21 days. The temperatures are noted at particular intervals of time. The temperature variations are shown in Fig.2.As the temperature of hot water supplied to the generator from the single flat plate solar collector increases, the evaporator temperatures at inlet and outlet are decrease. It is also observed from the Fig.2 the difference between evaporator temperatures at inlet and outlet marginally increases as the time of operation increases. The temperature drop is found that in the range of 7 to 8^{0}C. Almost after two hours of operation there is no further drop is observed and it may be due to there is no change in supply water temperature to the generator. The maximum COP is in the range of 3 to 3.5 and actual COP is found in the range of 0.75 to 0.79.

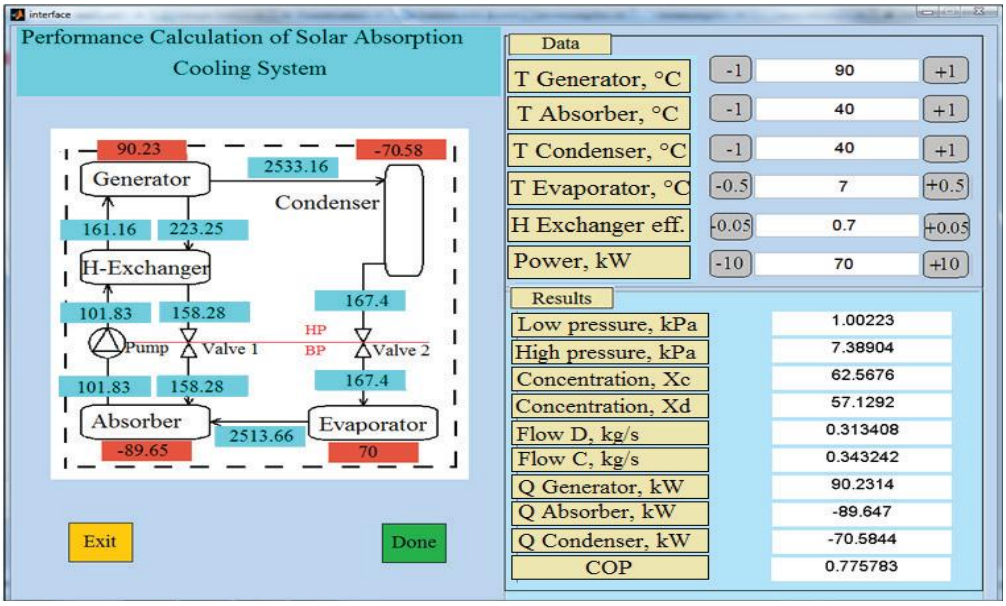

Fig.2 Observation in Cool pack of refrigeration cycle

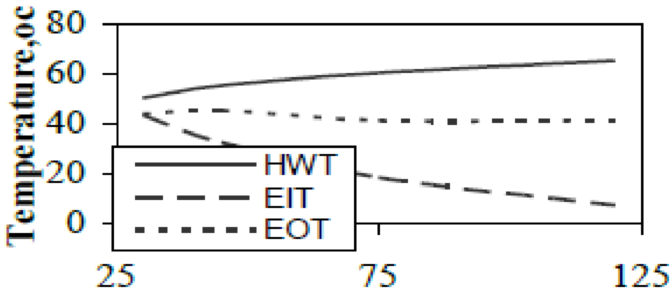

Fig.3 Temperature variation in the refrigeration cycle

HWT- Hot Water outlet Temperature from the solar heater
EIT - Evaporator Inlet Temperature
EOT – Evaporator Outlet Temperature

III. Conclusion

The following conclusions can be made from the present investigation

1. The Solar flat plate collector Water Heater (SWH) can be effectively used in summer to produce refrigeration effect using Vapour absorption refrigeration cycle.
2. The amount of refrigeration effect is based on the temperature of the hot water supplied to the generator.
3. The maximum drop in the temperature at the evaporator in the present work is estimated to be 7 to 8^0C.
4. The COP (Coefficient of Performance) of the system is about 0.78 against the maximum COP of the system 3.11.
5. The additional cost of the refrigeration cycle is very low.

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