Performance Study of Vapor Absorption Chiller Using Different Sources of Energy

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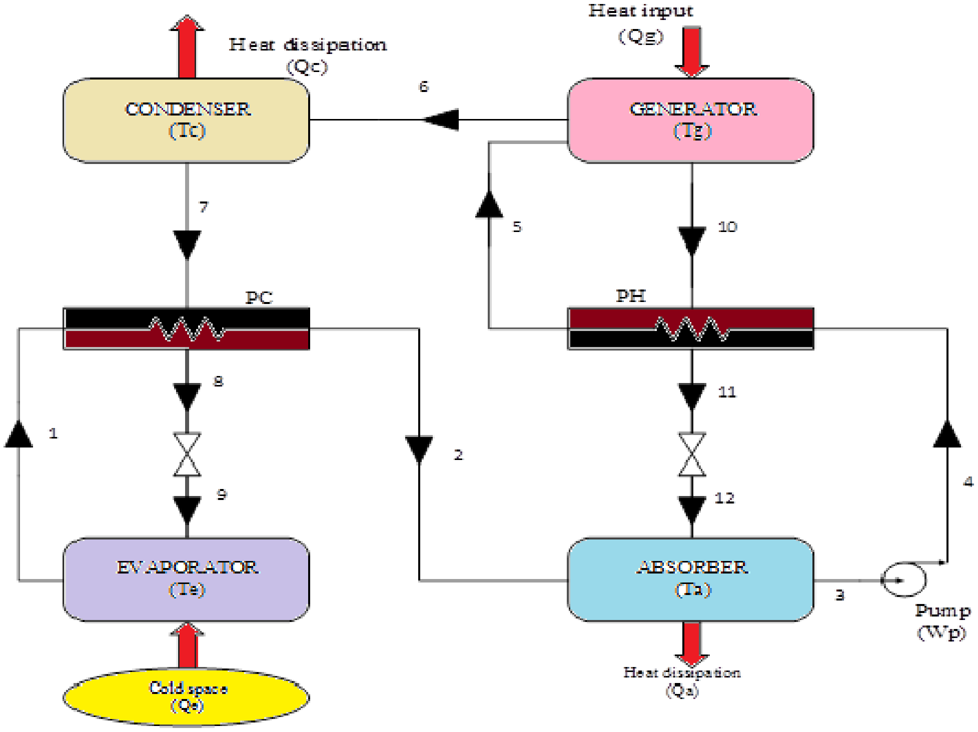
Abstract—*Thermodynamic analysis of single stage LiBr-H_2O absorption system has been carried out for different sources of energy; solar, biomass and thermoelectric. In the single effect cycle, the refrigerant leaving the evaporator is absorbed in a heat rejecting absorber. From the absorber, the solution is pumped to the generator via a pre-heater. From the generator, pure refrigerant (water) goes to the condenser, condenses and then the liquid refrigerant goes to the evaporator via a pre-cooler, thereby completing the cycle. In solo thermoelectric system, the investigation is focused on using heat generated from thermo-electric(TE) modules to drive a single stage absorption cycle. By using TE module not only heat that would normally be rejected to environment from the TE cooling system would serve as a heat source to drive the absorption cycle, but also recover a considerable amount of heat. In combined thermo-electric system, the heat from thermo-electric as well as that rejected by the absorber is used to heat the solution in the generatotor. By doing so, the coefficient of performance (COP) is increased by about 39.94% and optimum value of COP is found to be about 1.04. In this study, exergy analyses of single stage cycle has also been carried out for one tonnage of refrigeration (TR) capacity, using LiBr-H2O solution as working media. The analysis is done for the evaporator temperatures of 5, 7.5, 10 and 12.5 C and condenser temperature of 30 C and 35 C. Cost analysis of solo thermoelectric, solar and biomass system is also carried out for 1 ton of refrigeration. Total annual cost of solo thermoelectric system is more than double of solar system but it is very effective where space is a major concern e.g. space. For the condenser temperatures, 30 C to 35 C and evaporator temperatures of 5 to 12.5C, the value of maximum COP comes out to be 0.7716 to 0.8410 for biogas, 0.8012 to 0.8756 for solar and 0.6432 to 0.7654 for solo thermoelectric cycle. The value of maximum exergetic efficiency comes out to be 0.3012 to 0.4816 for biogas, 0.3109 to 0.5113 for solar and 0.2776 to 0.4563 for solo thermoelectric cycle. The minimum value of total exergy destruction comes out to be 0.0335 to 0.0815 kW for biogas, 0.0341 to 0.0821 kW for solar and 0.0345 to 0.0827 kW for solo thermoelectric cycle. Similar analysis can be carried out for combined thermo-electric system as well.*

Keywords: *vapor absorption, solar, biogas and thermoelectric*

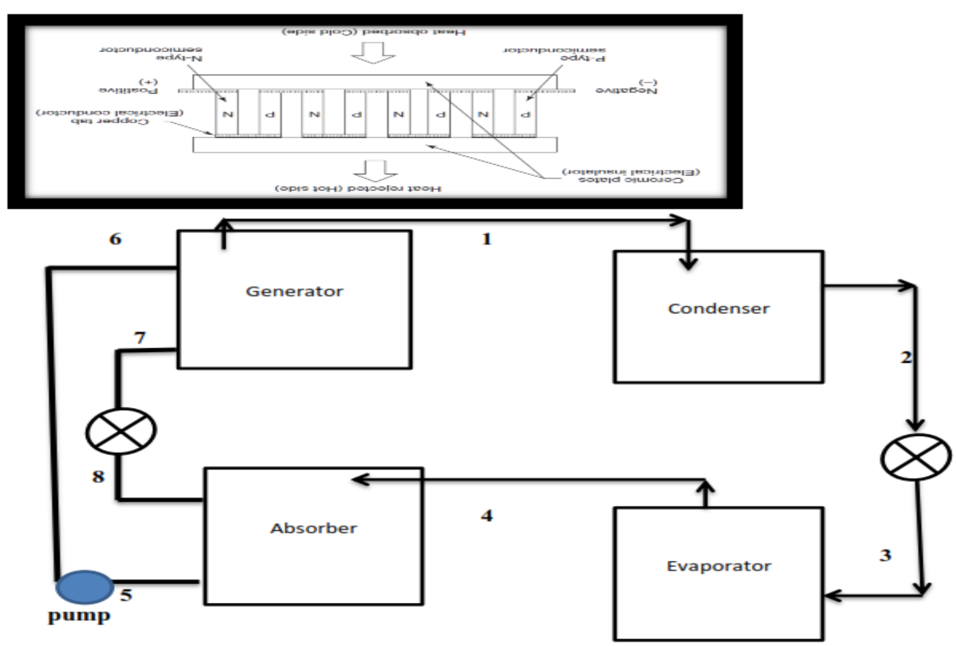
1. INTRODUCTION

Most of industrial processes uses a lot of thermal energy by burning fossil fuel to produce steam or heat for the purpose. After the processes, heat is rejected to the surrounding as waste. This waste heat can be converted to useful refrigeration by using a heat operated refrigeration system, such as an absorption refrigeration cycle. Electricity purchased from utility companies for conventional vapor compression refrigerators can be reduced. The use of heat operated refrigeration systems help reduce problems related to global environmental, such as the so called greenhouse effect from CO emission from the combustion of fossil fuels in utility power plants. Another difference between absorption systems and conventional vapor compression systems is the working fluid used. Most vapor compression systems commonly use chlorofluorocarbon refrigerants (CFCs), because of their thermo-physical properties. It is through the restricted use of CFCs, due to depletion of the ozone layer that will make absorption systems more prominent. However, although absorption systems seem to provide many advantages, vapor compression systems still dominate all market sectors. In order to promote the use of absorption systems, further development is required to improve their performance and reduce cost. Ferdinand Carre introduced a novel machine using water/ammonia as the working fluid. This machine took out a US patent in 1860. Machines based on this patent were used to make ice and store food. It was used as a basic design in the early age of refrigeration development. In the 1950"s, a system using lithium bromide/water as the working fluid was introduced for industrial applications. A few years later, a double-effect absorption system was introduced and has been used as an industrial standard for a high performance heat-operated refrigeration cycle. Absorption cooling systems have become increasingly popular in recent years from the viewpoints of energy and environment. From the energy point of view, source of energy to drive this system is low grade energy i.e. heat. Absorption refrigeration systems can be driven either by low-grade heat such as solar energy, geothermal energy, waste heat, natural gas, oil, steam and so forth. From environment point of view absorption system uses natural substances as working fluids, which does not cause ozone depletion and global warming. There are different combinations of working fluids possible for this cycle like H_2O-NH_3, LiBr-H2O etc. Most of the absorption cooling system use LiBr-H2O. However, LiBr-H2O system is simpler in design and operation, and also cheaper cost as compared to the NH3-H2O system. The LiBr-H2O system can operate at a low generator temperature with better coefficient of performance than NH3-H2O system. The use of NHO system is restricted in building applications because of the hazards associated with the ammonia whereas the LiBr-H2O system on the other hand is quite safe.

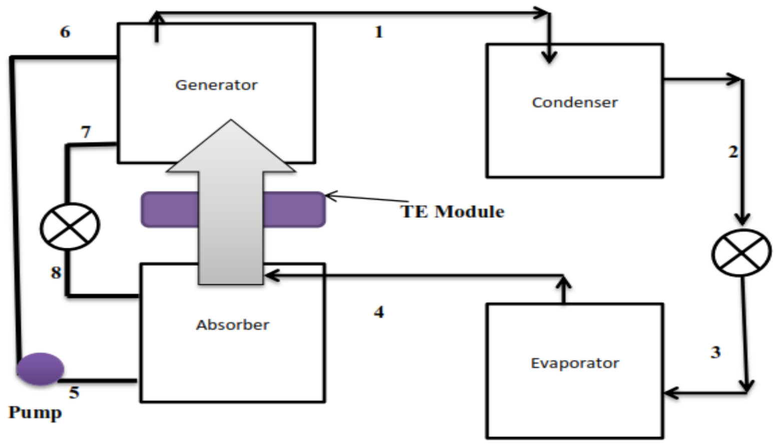
2. MODELS CONSIDERED IN THE ANALYSIS:



Model 1: Schematic diagram of single stage absorption system



Model 2: Schematic diagram of thermoelectric (TE) absorption cooling system



Model 3: Schematic diagram of combined thermoelectric (TE) absorption cooling system.

3. RESULTS

The following are the results obtained after First and Second Law of Thermodynamic analysis of the above models.

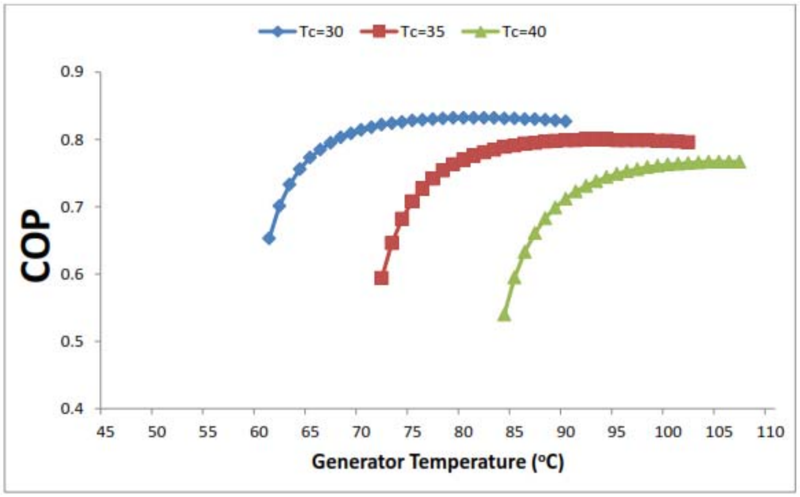


Fig. 1: Variation of COPbiogas with generator temperature T at various condenser temperatures T°C

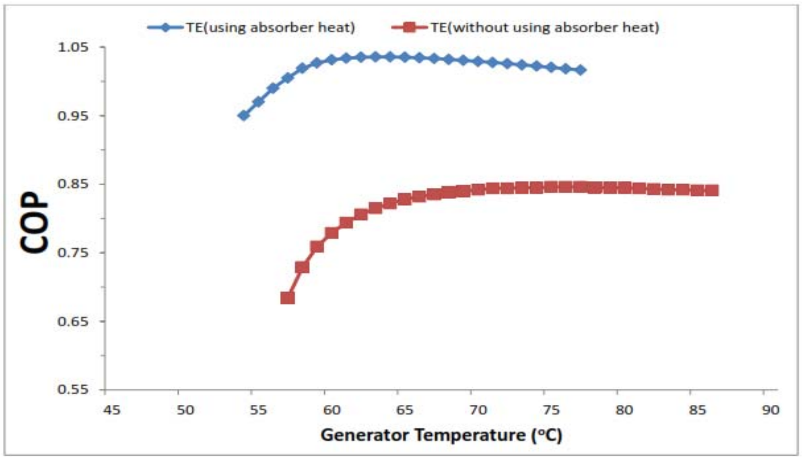


Fig. 2: Variation of COP_{TE} and COP with generator temperature for different evaporator temperatures at $T_{COMa}=T_c=30_oC$.

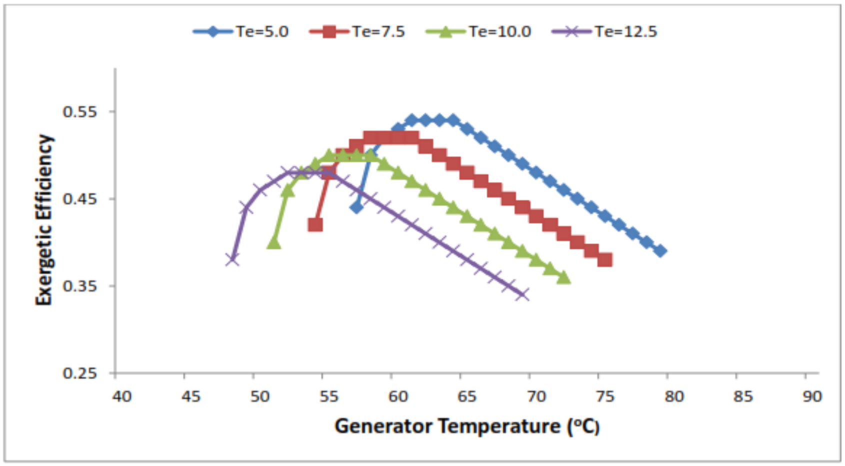


Fig. 3: Variation in exergetic efficiency (biogas) of single stage cycle with generator temperature at Ta=Tc=30oC.

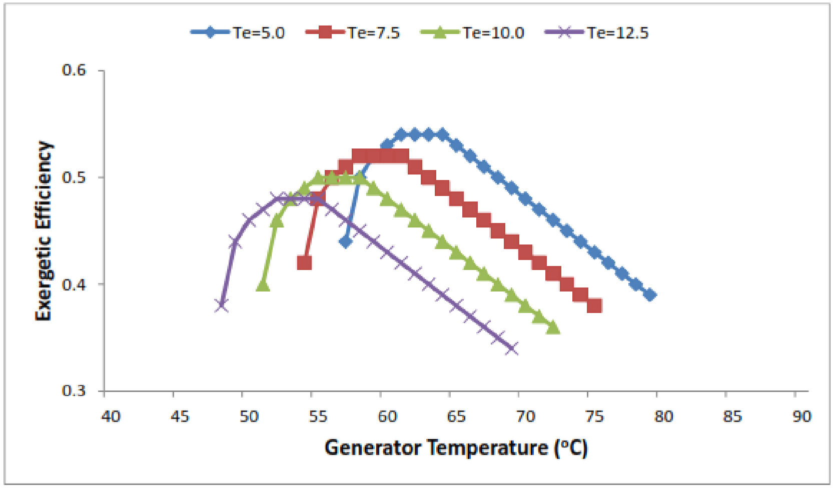


Fig.4:Variation in exergetic efficiency (solar) of single stage cycle with generator temperature at Ta=Tc=35oC.

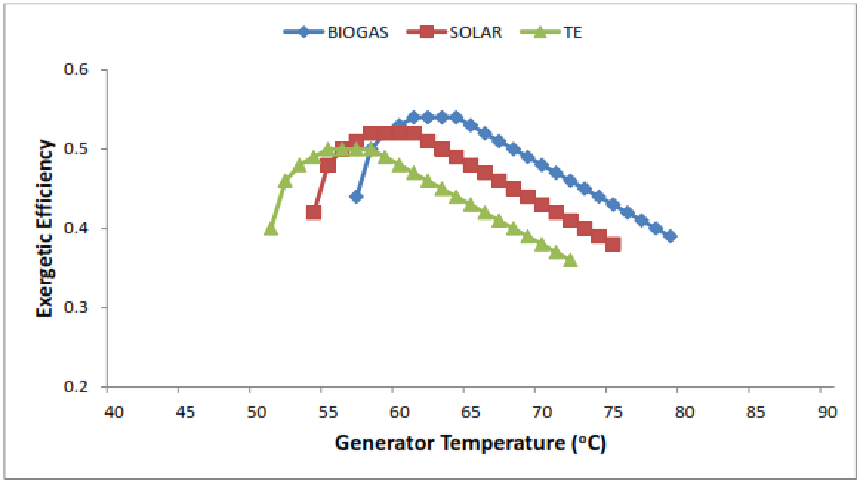


Fig. 5:Variation in exergetic efficiencies (biogas, solar and TE) of single stage cycle with generator temperature at Ta=Tc=35oC.

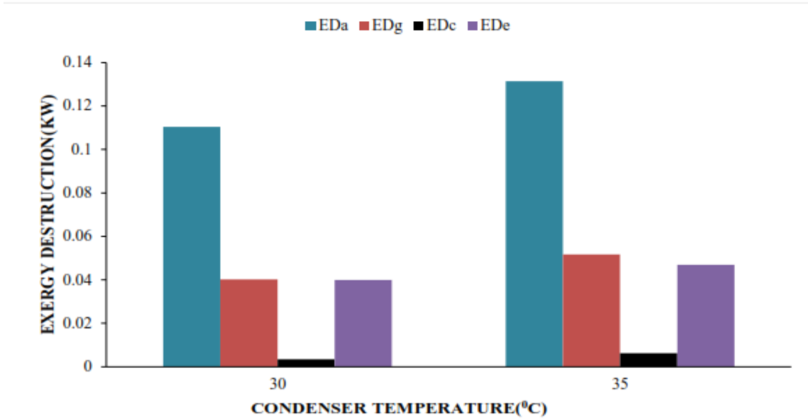


Fig. 6: Variation in Exergy destruction (biogas) of single stage cycle with condenser temperature (⁰C).

4. CONCLUSIONS

1. The coefficient of performance of single stage LiBr-H2O vapour absorption cycle increases with increasing generator temperature to which heat is supplied upto a certain limit and then decreases
2. Lowering of the evaporator temperature and raising of the condenser temperature leads to decrease in the coefficient of performance.
3. The coefficient of performance of the system using solar energy as input source of heat is slightly higher than that of using biomass energy and thermoelectric energy.
4. Annual cost of thermoelectric energy is much higher than both biomass and solar energy but because of less space occupied it is very effective in such industries where space is a major concern e.g. space industry.
5. Annual cost of solar energy is higher than that of biomass energy but because of low heating value biomass energy is not preferable.
6. When working in combined mode coefficient of performance of thermoelectric system is increased by 39.94%.
7. Irreversibility of system increase with decrease in evaporator temperature and increase in condenser temperature.
8. Exergetic efficiency decreases with increase in evaporator temperature and condenser temperature.
9. Exergy destruction in absorber is higher as compared to other components for all the three sources.
10. Irreversibility of system first decreases with increase in generator temperature shows a minima and then increases.

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