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A Comparative Study of Electrolux VAR System Using Electric Heater and IC Engine Exhaust as Heat Sources

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ABSTRACT

This paper presents the results obtained from the experimentation carried out on an experimental setup of NH3-H2O Electrolux system. Common experiences say that introduction of mechanically driven air conditioning system in car reduces fuel economy by 10%. Being one of the leading importers of crude oil and part of tropical region, this fuel consumption cost millions of dollars to India. Current energy scenario in world demands fuel conservation. Currently used mechanically driven air cooling system in cars can be replaced by vapor absorption refrigeration system. The system that was later introduced uses heat as input source, which is readily available from automobile exhaust. In testing electric heater has been used as a heat input source. Though second law of thermodynamics and Carnot theorem have stated that maximum coefficient of performance (COP) of a refrigerator depends on temperatures of source and sink, coefficient of performance is also dependent of thermodynamic properties of refrigerant, absorbent, and their mixture. This paper focuses on experimental analysis of 'Electrolux System' using electric heater and IC engine as heat source and the conclusions have been summarized. Purpose of the this paper is to present performance of system using high grade form of energy and put upper limitations of performances for further experiments carried out using low grade energy.

Keywords- Electrolux vapor absorption refrigeration system, aqua-ammonia, COP, refrigerating effect

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I. INTRODUCTION

Energy management plays a vital role as energy consumption has increased in recent years. Increased energy consumption has lead to fast depletion of natural resources, increased pollution and global warming. Hence, more and more focus is set in the research field on developing ways to minimize energy losses. Various methods are employed to reduce electric power and thermal energy consumption. It includes Waste heat regeneration which is an important method to reduce the thermal energy losses. This can be applied to refrigeration system working on vapour absorption cycle.

Refrigeration and air-conditioning systems use large amount of total energy produced. This is because it uses vapour compression cycle which requires compressors. But, on the other hand, vapour absorption system works on Waste heat which is low grade energy. This refrigeration system uses heat from steam or from any other source as input. Vapour absorption system works on aqua-ammonia or LiBr-H_2O as refrigerant. So, they are more eco-friendly than HCFCs and CFCs used in vapour compression cycle. Basically, in absorption system, compressor is replaced by pump, absorber and generator [1].

Absorption system has many applications in industries and large food storage plants. As this system works on low grade energy, it can be easily used for cooling of an automobile cabin using heat from its exhaust gases. The objective of this paper is to compare the performance of vapour absorption system working on heater and on exhaust gases of a petrol engine as source [2]. This is done by calculating the Coefficient of Performance over different generator temperature.

Abbreviations

T_1-Boiler Temperature (^oC)
T_2-Temperature after Boiler (^oC)
T_3-Condenser Inlet Temperature (^oC)
T_4-Condenser Outlet Temperature (^oC)
T_5-Temperature before Evaporator Inlet (^oC)
T_6-Evaporator Inlet Temperature (^oC)
T_7-Evaporator Outlet Temperature (^oC)
T_8-Absorber Inlet Temperature (^oC)
T_9-Absorber Outlet Temperature (^oC)
T_{10}-Absorber Vessel Outlet Temperature (^oC)
T_{11}-Refrigerator Cabinet Temperature (^oC)
t- Time taken for ten flashes (seconds)
T- Time of reading
RE- Net Refrigeration Effect (KJ)
COP- Coefficient of Performance

II. SYSTEM DESCRIPTION

System used for experimentation is (DOMETIC). Refrigerator cabin dimensions are 0.438 m* 0.295 m* 0.245 m. System uses air cooled conditioner and provision is made to insert electric heater or exhaust of car. System is well insulated using polystyrene. System is provided with electric meter so as to calculate electricity consumption.

Basic vapour absorption system consists of Generator, Condenser, Expansion Valve, Evaporator, Absorber and Pump. When aqua-ammonia is used as a refrigerant, water acts as absorber while ammonia acts as refrigerant.

Electrolux system is a special type of vapour absorption system. It is a three fluid system which uses hydrogen gas along with ammonia and water. There is no requirement of pump for circulation of refrigerant. Hence, there are no moving parts in the system. It works on the principle of 'Thermo-siphoning' [3]. The circulation of the refrigerant is due to temperature gradient and gravity. Ammonia vapours rise up from generator due to lower density while condensed ammonia in absorber coils flows under the action of gravity into the absorber vessel [2][9].

Working of the system is as follows-

1) Heat input is given to the generator. This heat is utilized to separate ammonia from strong aqua-ammonia solution. As boiling point of ammonia is lower than that of water, it boils and is directed towards condenser and the water flows back to absorber vessel with the help of gravity.

2) Ammonia vapours are converted to liquid in the condenser. This liquid is then mixed with hydrogen gas in the absorber which lowers the partial pressure of ammonia. Hence the temperature of ammonia is reduced.

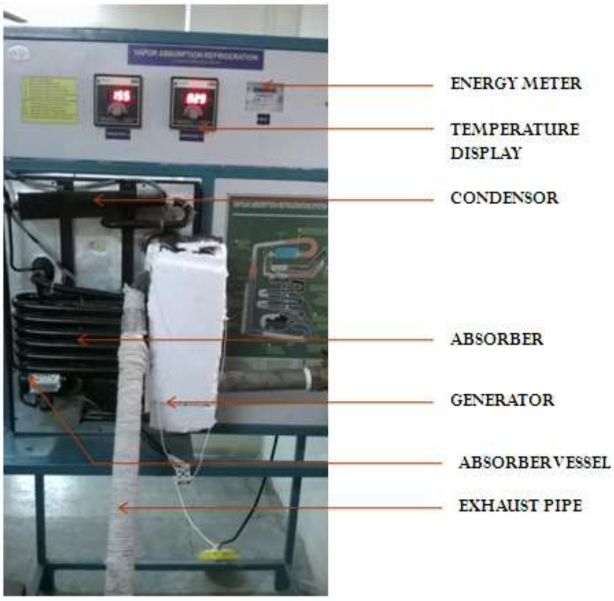

FIGURE 01: Experimental Setup

3) This liquid ammonia reaches in evaporator where it absorbs heat and evaporates. It produces refrigeration effect. This ammonia and hydrogen gas mixture reaches absorber coils where it is mixed with separated water in the generator [4]. As water has high affinity for ammonia, it absorbs ammonia from the mixture and the strong aqua-ammonia solution is formed. This solution is collected in the absorber vessel and the hydrogen gas rises back to the top [5][7][8].

4) Strong solution in absorber vessel is passed to the generator and the cycle is repeated [1].

III. RESULT

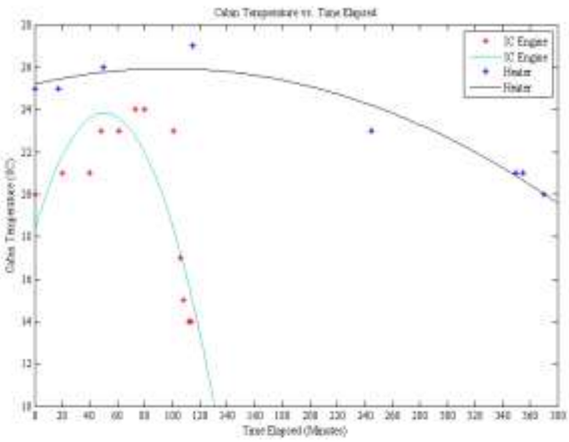

FIGURE 02: Cabin Temperature vs. Time elapsed

Figure 02 shows a comparison of change of cabin temperature with respect to time for electric heater as well as exhaust gas from IC engine. It is clear that the time required to achieve Lower temperatures in case of IC engine is far less than electric heater. Also the temperature achieved for exhaust gas as input heat source is considerably less than the temperature obtained in case of electric heater as input heat source. Initially a rise is seen in cabin temperature and then onwards temperature in the cabin decreases. The initial rise in the cabin temperature is said to be due to insufficient amount of ammonia vapours separated from the strong aqua-ammonia solution. There is a difference of almost 4 hours in the time required to obtain steady state cooling. Faster cooling was obtained in case of exhaust gases as input heat source.

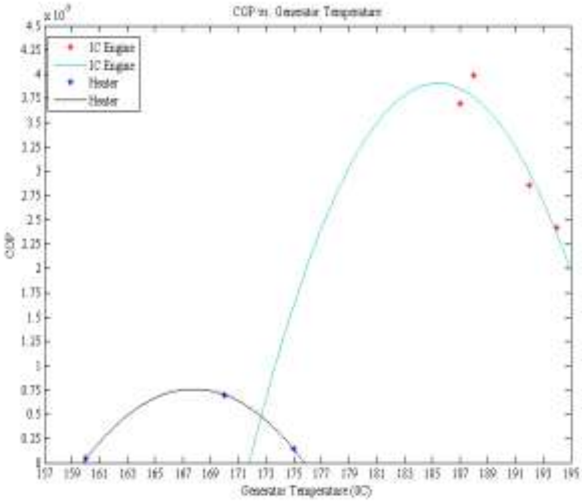

FIGURE 03: COP vs. Generator Temperature

Figure 3 shows the variation of COP against Generator temperature. Literature reviews have shown that generator temperature plays a crucial role in determining the COP of the system. For both input sources the COP initially increases with increase in generator temperature, attains a maximum value and then decreases further. A very largedifference was observed in the values of COP. For electric input heat source the maximum COP was around 0.0006,

Whereas for exhaust gases as input heat source the COP was 0.04. This can be attributed to larger heat supplied by exhaust gases to the generator. For the given VAR system the optimum generator temperature for maximum COP is 185^{0}C to 190^{0}C.

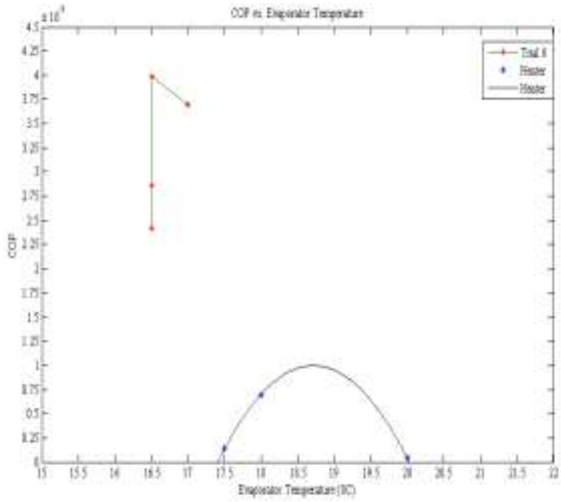

FIGURE 04: COP vs. Evaporator Temperature

Figure 4 shows variation of COP with Evaporator temperature. The evaporator temperatures obtained in the trial using electric heater were considerably higher compared to the temperatures obtained by using exhaust gases as heat source. This may also be due to the low COP obtained for electric heater as heat input. Also again it can be seen that COP is maximum for a particular evaporator temperature and partial pressure of ammonia in evaporator coils needs to be calibrated keeping this in consideration. It is evident from the plots that COP is more in case of IC engine for lower evaporator temperatures. The variation of COP with electric heater is more pronounced than exhaust gas heat input.

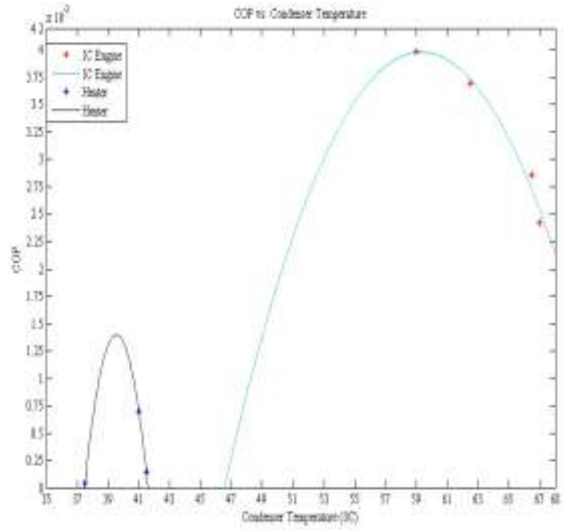

FIGURE 05: COP vs. Condenser temperature

Figure 5 shows variation of COP with respect to condenser temperature. Although COP does not depend much on condenser as condenser performance is restricted by ambient air conditions. Higher COP was obtained for electric heater for condenser temperature of 40^{0}C to 45^{0}C, whereas maximum COP was obtained for exhaust gas as input at condenser temperature of 60^{0}C. Better Air circulation over condenser is always advisable.

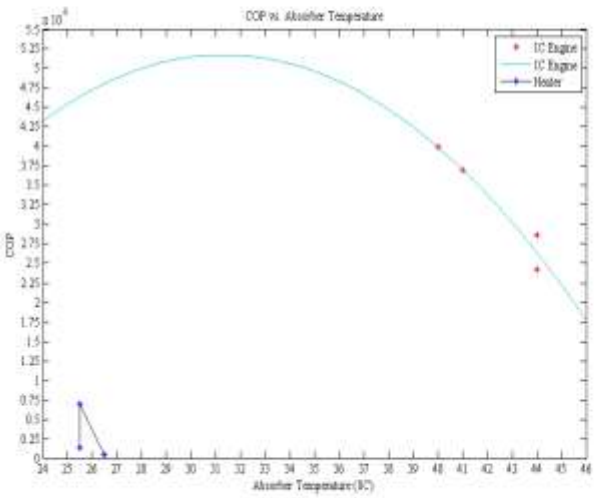

FIGURE 06: COP vs. Absorber Temperature

Figure 6 shows variation of COP with respect to absorber temperature. Absorber temperature also does not influence COP to a larger extent. But higher absorber temperatures need to be avoided as higher temperatures lower the solubility of ammonia vapours in weak solution in absorber vessels which may result in less refrigeration effect for same amount of generator heat input and hence decrease in COP of the system. In this case the experimental results are in agreement with common observations. COP is seen to lower for higher absorber temperatures for both type of input heat sources.

IV. CONCLUSIONS

The less values of COP obtained highlights the main drawback of system, which is less efficiency. Performance of system is highly governed by many factors. It is also known and concluded that system is a combination of refrigerator and pump. Average Generator temperature is the factor which dominates the performance of system. Currently it is observed that efficiency increases with respect to average generator temperature; thus the low COP would have been because of temperature limitation in experiment and COP may rise if temperature is increased. Though average temperatures of condenser and absorber have effect on performance of system it is not much dominating. Since every individual component of system is an individual heat exchanger there is much scope for improvement in performance. Also it is experienced that in spite of proper insulation heat loss is significant and it gives a clue for improvement. In spite of being low COP it is concluded that system is feasible for use in automobile cooling and system performance can be improved in future experiments.

The comparative study concludes that performance of the Electrolux VAR system was better with input heat source as exhaust of IC engine. Exhaust gases were able to achieve higher generator temperatures up to the optimum limit and hence COP and the time required for cooling also improved significantly.

V. FUTURE SCOPE

Further same experimentation will be carried out using exhaust gas from 3 cylinder 800 CC engine as heat source. Further combination of electric heater and car exhaust will be used as heat input source. Main Focus of experimentation will be on checking feasibility of exhaust driven Electrolux system for air cooling in cars.

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