Experimental Investigation and Performance Evaluation of a Three in one Vapour Compression System using Refrigerant R134a.

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Abstract:- **The present research is concerned with the study and experimental investigation of the effect of HFC refrigerant R134a on a vapour compression refrigeration system by using two expansion devises with the conservation of energy by waste heat recovery system. Here two different evaporators are used for air cooling and water chilling respectively and a water cooled condenser is used to produce hot water. The existing system can be easily retrofitted as a waste heat recovery device and the existing R22 refrigerant can be replaced by R134a with minor modifications. R134a play a vital role for the protection of global environment and maintain ecological balance, from the view point of energy conservation. The maximum temperature achieved in water tank with 50 litre of water is 45 C during 3 to 4 working hour. After that performance of system decreases so it needs a regular use of that hot water which can be used for household and industrial purposes.**

1. INTRODUCTION

Energy saving has become one of the key issues not only from the view of energy conservation but also for the global environment. Waste heat is the heat generated from most of the operations of system and then it is dumped into the surroundings even though it could still be utilized for some other beneficial purposes. This waste heat can be utilized from the condenser of the air conditioning unit and utilized for some other beneficial work. For this water cooled condenser is employed in the air conditioning system.

Most air conditioning systems affect the environment the following ways:

1. Consumes considerable amount of electricity and so it rejects a large amount of heat in the condenser. The heat rejected from the air conditioners is one of the causes for global warming.
2. Contributing to the greenhouse effect as energy consumers and producing CO_2, as well as through the use of organic substances in the cooling cycle.
3. Damaging the ozone layer as a result of the use of CFCs and HCFCs.

The present study mostly concentrates on the experimental investigation of a 3-in-1 vapour compression refrigeration cycle. The refrigerant R134a is used as working fluid. The effect of main parameters of performance analysis such as refrigerant type on refrigerating effect (RE), volumetric refrigerating capacity (VRC) and COP are investigated.

2. METHODOLOGY

The refrigeration effect is obtained in the cold region as heat is extracted by the vaporization of refrigerant in the evaporator. The refrigerant vapour from the evaporator is compressed in the compressor to a high pressure at which its saturation temperature is greater than the ambient or any other heat sink. Hence when the high pressure, high temperature refrigerant flows through the condenser, condensation of the vapour into liquid takes place by heat rejection to the heat sink as shown in fig (a) [11].

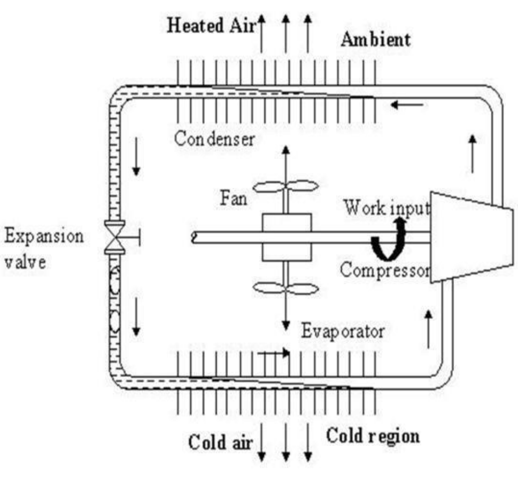

Fig (a). Vapour Compression System

To complete the cycle, the high pressure liquid is made to flow through an expansion valve. In the expansion valve the pressure and temperature of the refrigerant decrease. This low pressure and low temperature refrigerant vapour evaporates in the evaporator taking heat from the cold region. It should be observed that the system operates on a closed cycle. The system requires input in the form of mechanical work. It extracts heat from a cold space and rejects heat to a high temperature heat sink.

Kaushik and Singh [1] have found that 40% of condenser heat can be recovered in a refrigeration unit by experimentation with waste heat recovery system through the Canopus heat exchanger for a particular set of operating condition.

Retrofitting the WHRS in the domestic refrigerator of 165 liter, waste heat can be recovered and can be further used for different household and industrial purposes[2]. P. Sathiamurthi and PSS. Shrinivasan [3,4] discussed in studies on WHRS from an air conditioning unit that the low grade energy can be recovered and utilized without sacrificing comfort level, which is economically viable. F.N.Yu, K.T.Chan [5] discussed the various improved condenser design for an air cooled chillers. E.F. Gorzelnik[6] experimentally stated the recovery of energy in the heat of compression from air conditioning, refrigeration, or heat-pump equipment in 1977.M.Bojic(2001) [7] studied and explained the heat rise in environment due to heat rejected from the condenser unit of an air Conditioner. In ASHRAE handbook [8] energy consumption of Air Conditioning unit and energy efficient buildings and plans are discussed in detail in 2008. An experimental study on the performance evaluation of a domestic water-cooled air conditioner (WAC) using tube-in-tube helical heat Exchanger for preheating of hot water which is utilised for domestic purposes [9]. From experimental analysis, it has been concluded that by supplanting the normal Air Conditioner will vanguards to rescue 4 numbers of LPG gas cylinders per year. This not only saves the cost but also it bulwarks the environment by truncating the global warming engendered because of LPG gas [10].

From the above literature survey it can be concluded that the waste heat from the condenser can be effectively utilized for various purposes. An attempt has been taken to improve the waste heat recovery from air conditioning unit by using different refrigerants that can be compatible with the existing system and are ozone friendly.

3. EXPERIMENTAL SETUP

A typical vapour compression cycle consists of mainly four major parts viz. Compressor, condenser, throttling valve and evaporator. Fig (b) shows the schematic representation of the experimental test setup. It is a vapour compression refrigeration system with multi evaporators at different temperatures with single compressor, individual expansion valve and back pressure valve. The system is retrofitted with a water cooled condenser. The condenser is immersed in a tank (40 cm X 50cm X14 cm) having inlet for cold water and outlet for hot water. A glass tube rotameter is used to measure the mass flow of refrigerant. The test setup consists of three heat exchangers i.e. two evaporator coils and a condenser coil. One of the evaporator coil is enclosed in an insulated cabined which works as a chiller. To sense the temperature at different points six thermocouples are provided at various inlet and exit ports in the system. Another thermocouple is used to sense the temperature of the chiller. A thermometer is used to measure the temperature of the water tank. Three pressure gauges are provided on the control panel which shows the condenser pressure, and the pressures of the two evaporators.

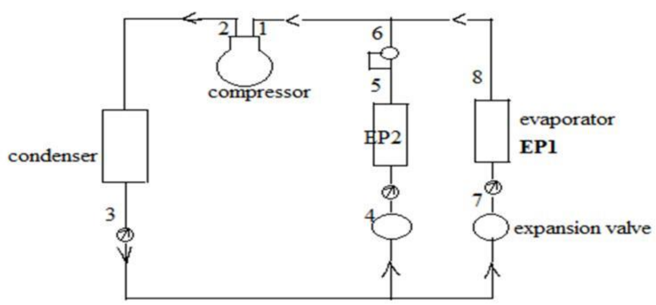

Fig (b). Block Diagram of system

4. EXPERIMENTATION AND MEASUREMENT

The experimental setup as shown in figure (c), consists of two evaporators and one condenser. One evaporator for air cooling, the other evaporator for water chilling and the water cooled condenser for water heating. The specification of the different components is shown in table 1. For the performance evaluation of the system here we use HFC refrigerant R134a. The properties of the refrigerant is given in table 2. First of all, the solenoid valve is closed and the flow of refrigerant is in only one evaporator i.e. the chiller unit and its performance is evaluated. Then the valve is opened and the performance is evaluated for all the three purposes that is water heating, water chilling and air cooling.

Fig.(c). Actual Experimental Setup

The heat recovery unit extracts heat from the hot refrigerant which is flowing through the condenser and rejects the extracted heat to the water in the tank.

Table 1. Specification of the system

Compressor	KCE444HAG, hermetically sealed
Condenser	Water cooled
Capillary tubes	3/8, 2 nos
Evaporator coil	10 x 11x 2
Low pressure gauge	0-250 psi, 2 nos
High pressure gauge	0-600 psi
Rotameter	60 LPH
Refrigerant	R134a
Thermocouples	6
Charged mass	1 kg

Table 2. Refrigerant properties

S.N.	Properties	R134a
1	Boiling point	-26°C
2	Latent heat	209.5 kj/kg
3	ODP	0
4	Toxicity	Non- toxic
5	corrosivity	Non corrosive
6	Evaporative pressure	1.63bar at -15°C
7	GWP	1200

Due to the temperature difference hot water in the tank moves upwards and cold water comes in from the bottom as the circulation is by thermosyphon effect. The heat recovery unit uses heating portable water for different household and industrial purposes. Amount of heat recovered depends upon discharge temperature compressor, load in the system and water quantity in tank. Therefore test are carried out at different load conditions by using three refrigerants to measure COP, and performance of heat recovery unit i.e. temperature in water tank for 4 hours.

5. RESULTS AND DISCUSSION

Results are the pure comparison between the vapour compression system with the heat recovery unit and with water cooled condenser to check actual COP and rise in

temperature of water in the tank. There are two different categories in which results are represented.

1. Performance of the system.
2. Rise in temperature of water in the tank.

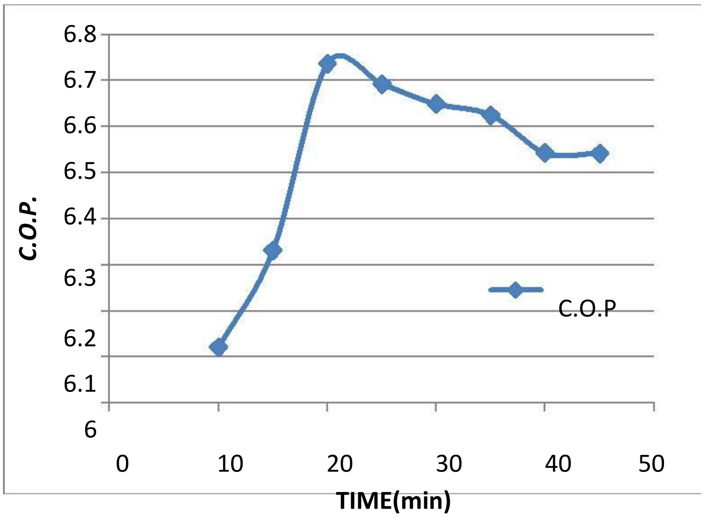

Fig. (d) .Actual C.O.P. of R134a v/s time.

Fig (d) shows the variation of actual COP of R134a with respect to time. The COP of the system increases upto a certain level and then starts decreasing.

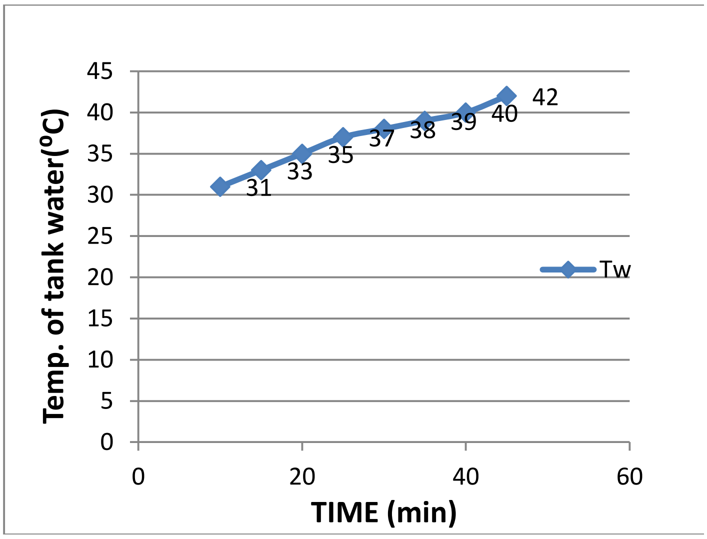

Fig. (e).Variation of tank temperature v/s time for R134a.

Graph (2) shows continuous variation of tank temperature with respect to time. As condenser heat rejection increases temperature of tank increases.

CONCLUSION

From the above results it is concluded that

- The maximum temperature achieved in the tank is 45^{0}C during 3-4 working hour.
- The COP of R134a is comparatively less than HCFC, but taking the environmental effects into consideration R134a can be preferred over other HCFC.
- The COP of the combined system is 37 % more than the COP of the system working on a single evaporator system.
- After recovering heat from the condenser the performance of system gets improved than the conventional air conditioning system.
- R134a can be a promising replacement for the conventionally used HCFC refrigerant, because of its low global warming potential and zero ODP.

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