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Experimental analysis on vapor compression refrigeration system by using eco-friendly refrigerant mixtures

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***Abstract*- This experimental investigation related with the performance evaluation of a refrigeration system by using various eco friendly refrigerant mixtures. The refrigerating system used for the evaluation works on (VCC) vapor compression cycle on the principle of heat is absorbed in an evaporator by evaporation process. Now days it is very important to increase the coefficient of performance (COP) of the refrigeration system and to increase the COP lot of researches are done. The eco friendly refrigerants used in the system to enhance the performance are R134a (Tetrafluoroethane), R290 (Isobutane). This experimental study contracts with a comparative analysis of the performance of various mixtures of refrigerants as described below with R134a kept as a comparative parameter. The above refrigerants are mixed on the basis on weight proportions in diverse ratios, and below mentioned mixtures used are:**

Test-1: R134a

Test-2: R134a - 80% and R290 - 20%

The usages of all CFC refrigerants are already phased out and Kyoto Protocol suggests that high (GWP) global warming potential of 1300 R134a may be phase out in upcoming days. So present experimental analysis has been done with the mixtures of hydrocarbon refrigerant as an alternate to a R134a refrigerant.

***Key words*- Vapor compression cycle, Refrigerants R134a and R290, COP, refrigeration input.**

1. INTRODUCTION

The Vapor Compression Refrigeration Cycle is very old near about 200 years ago it is invented and now days it becomes a crucial one. Now day it is discussed among the researcher that this method is going to inefficient and environmentally harmful, though it is still used in the industrial applications. This cycle uses CFC as well as non CFC refrigerants. In India, around 80 % of the domestic applications like refrigerators and air conditioner uses R134a as a refrigerant due to its best thermo physical and thermodynamic properties. United Nations Framework Convention on Climate Change (UNFCCC) formulated the Kyoto Protocol which asked to reductions in emissions of various six types of greenhouse gases and hydro fluorocarbons. In domestic applications of refrigeration systems more refrigerant consumptions is identified. So to develop and use of eco-friendly refrigerant is very essential in domestic application refrigerators.

2. COMPONENTS OF VAPOR COMPRESSION CYCLE:

Compressor: The hermetically sealed reciprocating compressor sucks the refrigerant from the evaporator at low temperature and low pressure refrigerant during its suction stroke and delivers it to condenser at high temperature and high pressure.

Condenser: This is the second device in the vapor compression cycle used to convert high temperature and high pressure vapor refrigerant in to the liquid refrigerant. The air cooled forced convection condenser is used in this cycle.

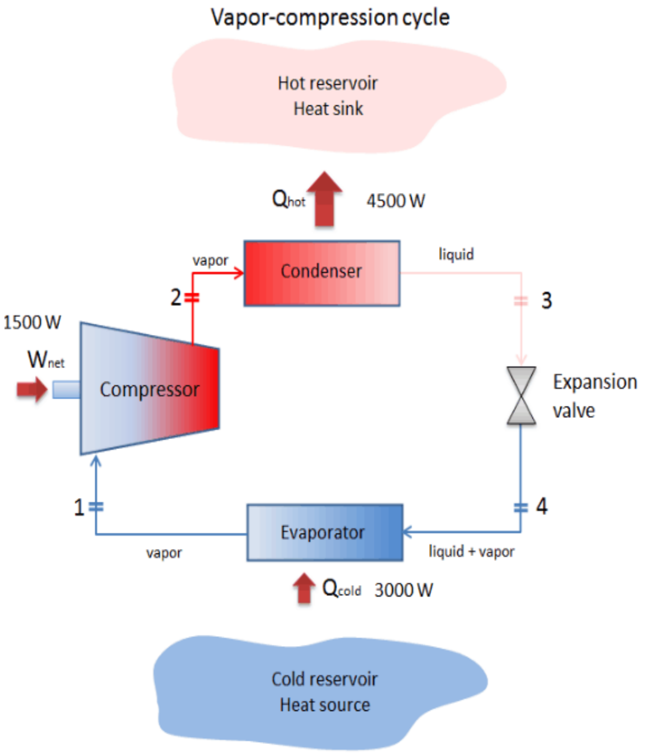
Expansion valve: capillary tube is used in vapor compression cycle as expansion valve along with solenoid valve. Large pressure drop takes place inside the capillary tube and low temperature liquid refrigerant is supplied to the evaporator.

Capillary tubes: Capillary tube is a very Small diameter tube made from copper or steel. The inside diameter of this capillary tube may vary from 0.5 to 2.28 mm (0.020 to 0.090). Capillary tube is one of the type of throttle device. Longer capillary tube and small in diameter capillary tube can produce a greater pressure drop and hence a large temperature drop occurs inside the capillary tube. The required length of this capillary tube of a specific diameter for an particular application is first roughly calculated by empirical calculations. Then it is further corrected by the experiments. This capillary tube is a not self-adjusting tube, therefore a it is selected for a specific set of conditions and load. Low and high sides equalize by this capillary tube as the refrigeration system stops working. The refrigerant quantity should be the same as given by the manufacturer of the refrigeration system. Since it equalizes the low side with the high side during the system stoppage, the suction of the compressor and idle pressures at the discharge should be equal.

The capillary tube is not costly and it is very simple device. Its property of pressure equalization is beneficial to the motor that it requires a very low starting torque motor.

Evaporator: Evaporator removes the heat from the product or foods stored in the refrigeration system. It extracts heat and liquid refrigerant is converted in to the vapor refrigerant inside the evaporator coil.

Varieties of evaporators are available in different shapes, designs and types to suit as per cooling requirements. Thus, we have a variety of types of evaporators, such as extended surface type, finned tube type, prime surface types, shell and liquid chillier, etc.,.



Source: https://www.nuclear-power.net

More and more liquid is vaporized by the load as the refrigerant passes through the evaporator. At the end of this evaporation process the refrigerant is purely in the vapor state and that too superheated. Thus the evaporator tubes are filled with a varying proportion of vapor and liquid. According to the load on evaporator the amount of liquid inside the evaporator will change. The evaporators used may be dry-expansion type or flooded type evaporator.

Refrigerant-R134a – This is most popularly common refrigerant used in a wide range of air conditioning and refrigeration applications,

Tetrafluoroethane is a gas used as primary refrigerant for air conditioners applications and domestic purpose refrigeration systems. Because of Ozon depletion by the CFCs and HCFCs *refrigerants*, the HFC *refrigerant* has been globally used as their replacement. Refrigerants R134a is the most popularly used refrigerant in domestic refrigeration systems. Kyoto protocol states that due to its high global warming potential, it must be phased out at the earliest. Hence we come up with several hydrocarbon mixtures of refrigerant as an alternative for R134a refrigerant.

1. Specifications of Compressor

• Working position Vertical

• Number of times of compression of gas Single stage

• Number of cylinders - One

• Method of compression Single acting

• Cooling system Air-cooled

•Motor use (Single phase)

•Compressor 1/6 hp, 2440 rpm

3. Evaporator

5. Energy Meter

2. Condenser

4. Pressure Gauges

7. Capillary Tubes

6. Control Valves

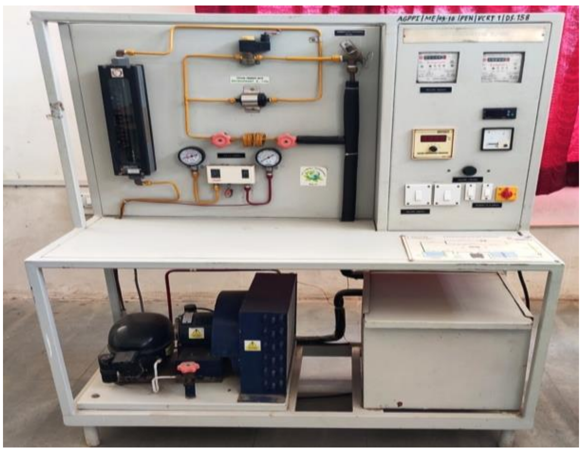
8. Channel Temperature Indicator

All the components are fitted and connections are given accordingly and all the gauges are fixed.

3. METHODOLOGY

DESCRIPTION OF THE TEST RIG:-Refrigeration test rig consists of a hermetically sealed compressor, air-cooled forced convection condenser, capillary tube with solenoid valve and an evaporator. The evaporator cools the water in a calorimeter. Output of heater provided in the calorimeter can be varied with the help of dimmer stat. Individual pressure gauges are used to measure the Evaporator and Condenser pressures. Five different thermometers are used to measure temperatures at different locations as per the Layout provided. Two separate energy meters are used to measure energy supplied to the heater and compressor. Suitable L.P. and H.P. cutout, Voltmeter and ammeter are used in the unit.

Experimental Setup



Source: RAC Laboratory Mechanical Engg. Department, A.G. Patil Polytechnic Institute, Solapur, Maharashtra

4. OBSERVATION:

Let,

P1- Evaporator Pressure

P2- Condenser Pressure

T1 -Temperature at Evaporator outlet

T2- Temperature at Compressor outlet

T3 -Temperature at Condenser outlet

T4- Temperature at Expansion valve outlet

Th- Time for 10 rev. on energy meter heater

Tc - for 10 rev. on energy meter Compressor

Temperature and Pressure observations Test-1: R134a

Time Th	Time Tc	P1	P2	T1	T2	T3	T4
Sec	Sec	Bar	Bar	^{0}C	^{0}C	^{0}C	^{0}C
14	20	8.602	2.95	44	36	6	15

Temperature and Pressure observations mixture-1-R-134a 80% and R290 20%

Time Th	Time Tc	P1	P2	T1	T2	T3	T4
Sec	Sec	Bar	Bar	^{0}C	^{0}C	^{0}C	^{0}C
12	18	9.302	3.12	48	32	4	13

Calcuations:

COP FOR Test-1 :

Actual COP

R act= Actual refrigeration effect = heat produced by heater

R act = 10/Nh X 3600/Th

R Act = 10/3200 x 3600/14

R act = 0.803 kW

W= Actual energy supplied to compressor

W= 10/Nc x 3600/Tc

W= 10/3200 x 3600/20

W= 0.56 kW

Actual COP = R Act / W

= 0.803 / 0.56

Actual COP = 1.43

COP FOR Test 2:

R act= Actual refrigeration effect = heat produced by heater

R act = 10/Nh X 3600/Th

R Act = 10/3200 x 3600/10

R act = 1.125 kW

W= Actual energy supplied to compressor

W= 10/Nc x 3600/Tc

W= 10/3200 x 3600/22

W= 0.511 kW

Actual COP = R Act / W

= 1.125 / 0.511

Actual COP = 2.20

5. RESULTS AND CONCLUSION:

This experiment investigated that the behavior of various refrigerant mixtures as a flowing liquid in a vapor compression cycle (VCC). The Mixture of refrigerant blend is used for this experiment using different components and proportions. Here R134a refrigerant is used as comparing parameter for the other refrigerant mixtures. By conducting the experimental analysis, we have found out that Test-2 R134a 80% and R290 20% given a highest COP and the Test-1 R134a have given a lowest coefficient of performance when compared to each other.

The Mixture-2 R134a 80% and R290 20% have shown a slight increase C.O.P by 0.77 when compared to the C.O.P of R134a on the same experimental setup. On analyzing the refrigeration effect, for a given time period Test-2 results better effect of cooling than Test-1 (RE by only R134a). But while comparing the work input data, the system when charged with Test-2 has operated with low energy consumption than R134a refrigerant.

If energy consumption factor considered then, it is understood that Test-2 R134a 80% and R290 20% can be used as an effective exchange refrigerant to R134a on a long term run. The results confirm that hydrocarbon mixtures have lower energy consumption. The overall (COP) coefficient of performance of the hydrocarbon mixtures proved that this will be the best alternative to phase out R134a.

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