Experimental Analysis of VCR by Using R290/R134a Blended Refrigerant

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Abstract- Now a day's refrigeration systems have shown many applications in both industrial and domestic Sectors. The majority of domestic refrigerators works on vapour compression system. Vapour compression system uses expansion valve to reduce the pressure of liquid refrigerant and delivers to the evaporator. The leakages of widely used hydro fluorocarbon refrigerants from refrigerator shows severe impact on the environment like global warming, ozone depletion, etc. In order to overcome this problem a mixture with Blend refrigerants by combining hydro fluorocarbons and hydrocarbons are used in this experiment. Blend refrigerants combining hydro fluorocarbons and hydrocarbons are good substitute to reduce global warming potential. In this present work the performance of domestic refrigerator is compared for R290 and R290/R134a refrigerants.

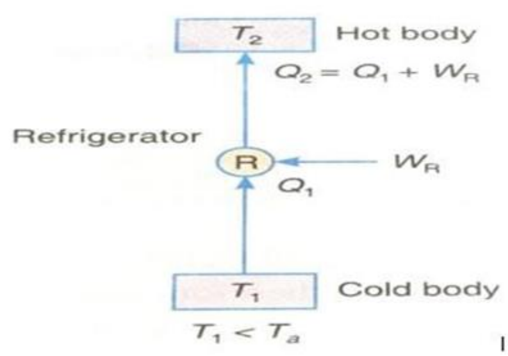
I. INTRODUCTION

- *Refrigeration:*

Refrigeration may be defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. In a refrigerator, heat is virtually pumped from a low temperature to a higher temperature. According to IInd law of thermodynamics, this process can only performed with the aid of some external work. It is thus obvious that supply of power is regularly required to device a refrigerator. Theoretically, a refrigerator is a reversed heat engine which pumps heat from a cold body and delivers it to a hot body. The substance which works in a pump to extract heat from a cold body and to a deliver it to a hot body is known as refrigerant.

The Performance of a #refrigerator is expressed by the ratio of amount of heat taken from the cold body (Q1) to the amount of work required to be done on the system (WR). This ratio is called as coefficient of performance. Mathematically, coefficient of performance of a refrigerator,

$$C.O.P = Q1/W_R = Q_1/(Q_2 - Q_1)$$



Types of refrigeration system,

1. Non cyclic refrigeration
2. Cyclic refrigeration
   - Vapour absorption refrigeration
   - Vapour compression refrigeration
   - Gas refrigeration
3. Thermo electric refrigeration
4. Magnetic refrigeration

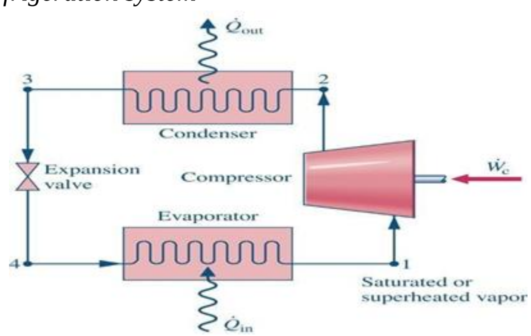
The above mention methods VCR system is widely used as its COP is very high compared to the remaining methods. The region for it is VCR cycle is very close to reversed Carnot cycle. Remaining methods are used according to the application.

- *Vapour Compression Refrigeration System*:

The basic components of VCR system are show in the figure which consists of an evaporator, compressor, condenser, and expansion valve. First low pressure and temperature vapour refrigerant from evaporator is drawn into the compressor through the inlet valve, where it is compressed to a high pressure and temperature. This high pressure and temperature vapour refrigerant is discharged into the compressor through the discharge valve. The high pressure and temperature vapour refrigerant is enters into the condenser, and condensed the high pressure and low temperature liquid refrigerant at the condenser outlet. The expansion valve is converted into low pressure and low temperature liquid refrigerant enters into the evaporator.

The VCR system is the ratio of net refrigeration effect (NRE) to the(Wc); therefore, the COP is increased by increasing the Net refrigerating effect and decreasing the compression work.

Basic components of a vapour compression refrigeration system



The vapour compression refrigeration system consists of four processes

1. Isentropic compression in a compressor
2. Constant-pressure heat rejection in a condenser
3. Throttling in an expansion device
4. Constant-pressure heat absorption in an evaporator

- *Isentropic Compression*:

In an ideal vapour compression refrigeration cycle, the refrigerant enters the compressor at state 1 as saturated vapour and is compressed isentropic to the condenser pressure. The temperature of the refrigerant is increases during compression. Isentropic compression process is too well above the temperature of the surrounding medium.

- *Constant-pressure heat rejection:*

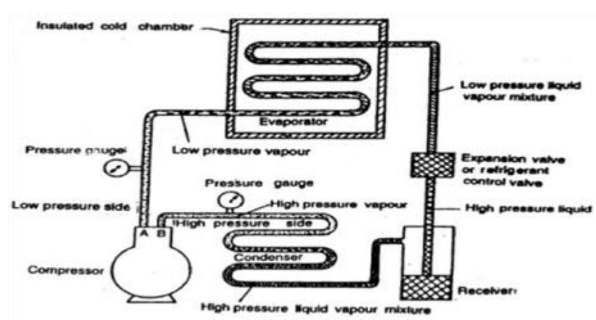
The refrigerant then enters the condenser as super-heated vapour at state 2 and leaves as saturated liquid at state 3 as a result of heat rejection to the surroundings. The temperature of the refrigerant at this state is still above the temperature of the surroundings. The condensed liquid refrigerant from the condenser is stored in a vessel known as receiver from where it is supplied to the expansion valve and then to the evaporator.

- *Throttling:*

The saturated liquid refrigerant at state 3 is throttled to the evaporator pressure by passing it through an expansion valve or capillary tube. The temperature of the refrigerant is drops below the temperature of the refrigerated space during this process. Some of the liquid refrigerant evaporates as it passes through the expansion valve.

- *Constant-pressure heat absorption:*

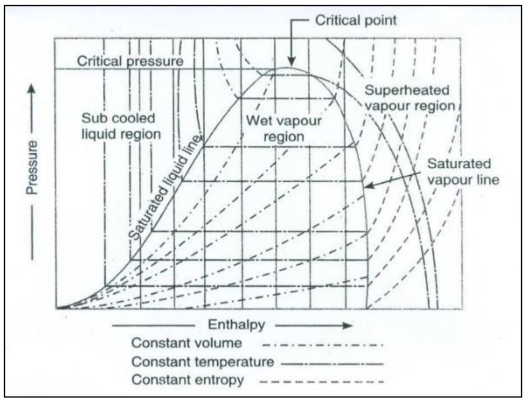
The refrigerant enters the evaporator at state 4 by flashing and some amount of refrigerant becomes vapour. As it passes through evaporator it absorbs heat from the refrigerated space and becomes vapour and enters into compressor and thus cycle repeats.



P- H Diagram

The most convenient chart for studying the behavior of a refrigerant is the p-h chart, In P-H chart they are three states liquid, solid, vapour states.

The explanation of chart is in which the vertical lines are represented by pressure and horizontal lines are represented by enthalpy. Some important lines are drawn in a p-h chart. The liquid saturated line and vapour saturated line meets into a curve at the critical point. A Liquid saturation line of temperature is equal to the saturated different pressures. Left side of the saturated liquid line is sub-cooled liquid region. The space b/w the liquid and the vapour lines is called wet vapour region and to the right of the saturated vapor line is a superheated vapour region.



II. ANALYSIS OF IDEAL VCRS WITH P-h DIAGRAM

The Pressure-Enthalpy (P-h) diagram of Vapour Compression Refrigeration System is represented in the figure. Analysis is carried out by using steady flow energy equation.

1. Compression Process:

The low pressure P_1 and temperature T_1 at vapour refrigerant is compressed isentropically. For reversible adiabatic or isentropic compression of 1kg of vapour the compressor work per kg input is given by,

$W_c = (h_2 - h_1)$ kJ/kg

Where,

Wc =compressor work

h_1=enthalpy of vapour refrigerant at the suction of the compressor.

h_2= enthalpy of vapour refrigerant at the discharge of the compressor

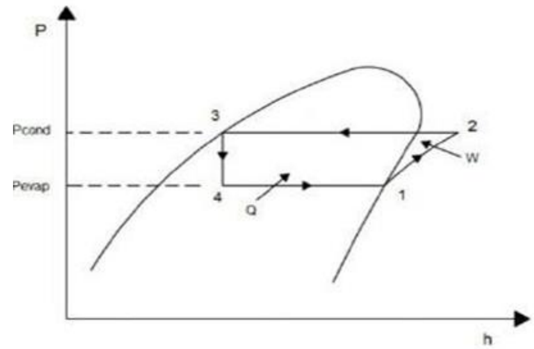


Figure: P-h chart for ideal VCRS system

2. Condensing Process:

The high pressure (P_1) and high temperature (T_1) at vapour refrigerant from the compressor are passed through the condenser where it is completely condensed at constant pressure (P_2) and temperature (T_2). The vapour refrigerant is changed into the liquid refrigerant.

$q = h_2 - h_3$ (kJ/kg)

Where,

h_2= enthalpy of super-heated vapour refrigerant at compressor exit (kj/kg).

h_3 = enthalpy of saturated liquid refrigerant at condenser exit (kj/kg).

q = heat rejected in condenser.

3. Expansion Process:

The high pressure and low temperature at liquid refrigerant is enters into the expansion value converts into the low pressure and low temperature at liquid refrigerant and then enters into the evaporator. The expansion process, pressure P_2 and pressure P_3 is same and temperatures T_2 and T_3 is also same, it is expanded by expansion process through the expansion valve to a low pressure P_4 is equal to P_1 and temperature T_1 is equal to T_4. During throttling process no heat is absorbed or rejected by the liquid refrigerants.

h3=h4

Where,

h_3= enthalpy of saturated liquid refrigerant at condenser exit. (kj/kg)

h_4 = enthalpy of refrigerant at inlet to evaporator. (kJ/kg)

4. Vaporizing Process

The liquid vapour mixture of the refrigerant at pressure $P_4=P_1$ and temperature $T_4=T_1$ is evaporated and changed into vapour refrigerant at constant pressure and temperature. During evaporation the liquid vapour refrigerant absorbs it latent heat of vaporization from the medium (air, water or brine) which is to be cooled. This heat which is absorbed by the refrigerant is called refrigerating effect and it is written as R_E. The process of vaporization continues up to point 1 which is the starting point and thus the cycle is completed.

The refrigerating effect of the heat absorbed or extracted by vapour refrigerant during evaporation per kg of refrigerant is given by,

$$R_E= h_1 - h_4$$

h_1=enthalpy of vapour refrigerant at the suction of the compressor. (kJ/kg)

h_4 = enthalpy of refrigerant at inlet to evaporator. (kJ/kg)

It may be noticed from the cycle that liquid vapour refrigerant has extracted heat during the evaporation and the work will be done by the compressor for isentropic compression of the high pressure and temperature vapour refrigerant.

Coefficient of Performance:

$$COP= \frac{REFRIGERATION\ EFFECT}{WORK\ DONE}$$

III. LITERATURE REVIEW

P. A Domanski and Didion [1] In this effect of performance parameters are evaluated by placing suction line/liquid line heat exchanger in the basic vapour compression refrigeration system. It examines cycle parameters and refrigerant thermodynamic properties that determine whether the installation results in improvement of COP and volumetric capacity. As a result of employing suction line/liquid line heat exchanger high pressure refrigerant is sub cooled at the expense of superheating of vapour enter into a compressor.

M. A. Sattaret, et.al. [2] Investigated and compared the performance of the refrigerator using R600a, R600 and a ternary mixture of mixture of R290/R600a/R600 as refrigerants with theR134a. The impacts of evaporator and condenser temperatures on COP, refrigerating impact, blower force and warmth dismissal proportion were examined. The outcomes show that the blower devoured 3% and2% less energy than that of R134a at 28°C encompassing temperature whenR600a and R600 was utilized as refrigerants separately. The blower force and COP of hydrocarbons and their mixes shows that hydrocarbons can be utilized as refrigerants in the domestic refrigerator. The COP and other results obtained from the experiments show a positive indication of using HC as refrigerants in a domestic refrigerator.

A.S. Dalkilic and S. Wong wises [3], Developed a new cycle with Diffuser at compressor in a VCR system utilizing R134a, R152a, R32, R290, R1270, R600 and R600a was done for various ratios as a refrigerant to upgrade the exhibition of the cycle. Results got and indicated that there was increment of 8.6% in coefficient of execution of the new pressure refrigeration cycle when contrasted with the ordinary fume pressure refrigeration cycle with R134a. The test shows that the dynamic energy acquired at blower source was changed over into pressure energy. Also, the temperature, pressure at the diffuser source was expanded when contrasted and that at blower source. Because of this the decrease in blower work happens and COP of the framework was expanded.

The analysis shows that the time needed for the freezing in evaporator was additionally snappier than that of normal cycle.

IV. EXPERIMENTAL SETUP & PROCEDURE DESCRIPTION OF EXPERIMENTAL SET UP:

The experimental set up consists of a160 liters capacity of domestic refrigerator, designed to work with R-290 refrigerant and having main components.

- Experimental refrigerator

Figure: R134a Refringent

Domestic Refrigerator specifications:

Refrigerant	R-290 + R-134a
Refrigerator capacity	160 litres
Compressor Capacity:	0.14 HP

Condenser Sizes:

Length	9.35m
Diameter	6.35mm

Capillary Tube:

Length	2.355m
Diameter	0.925mm

Evaporator:

Length	7.75m
Diameter	6.35mm

V. COMPONENTS USED IN THE EXPERIMENT

The major components used in experiment are as follows.

1) Compressor
2) Condenser
3) Filter
4) Expansion device (capillary tube)
5) Evaporator

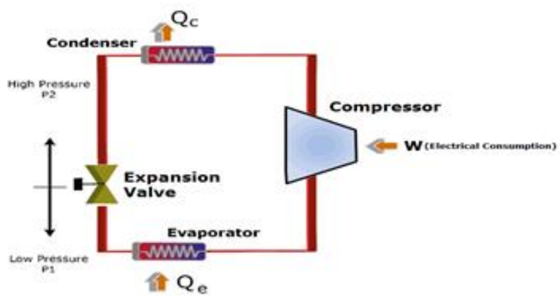


Figure: Line Diagram for experimental refrigerator

Compressor:

Compressor is the mechanical device in vapour compression refrigeration system; it is used to device motor. The purpose of compressor is continuously extract low pressure vapour refrigerant from evaporator and compresses it to high pressure vapour refrigerant. It is placed in between evaporator and condenser, and at low pressure side of refrigerator. compressor can handle the gaseous phase or vapour state of the working substance.

Figure: R290 Compressor

Condenser:

The condenser consists of coils of thin copper pipe in which the high pressure and temperature vapour refrigerant is cooled and condensed by the process of natural convection. The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air. In this experiment air cooled condenser of length 9.35meters and 6.35 tube diameter is used. The condensing medium in this experiment is air. Due to the natural convection of heat transfer the high temperature available at compressor outlet is delivered to the atmosphere in the condenser. Theoretically this entire process is taken at constant pressure.

Figure: Condenser

Filter:

Any impurities present in refrigerants (or) any impurities entered at the time of charging may cause the blockage of refrigerant flow. So to obstruct any impurities present in the system filter is used. Filter is located in between the condenser and expansion valve (capillary tube) in the refrigeration cycle. The refrigerant is in liquid stage after condenser, so it is easily filtered in filter.

The capillary diameter is very small around 0.95mm. So it's necessary to filter any impurities before entering in to it. In this experiment a heavy filter is used.

Figure: Filter

Expansion Device (Capillary Tube):

Expansion valve used in domestic refrigerator is capillary tube. A Expansion valve is a lengthy, narrow tube of same diameter throughout the length. Diameter of expansion valve is vary from 0.5 mm to 3mm and the length ranges from 1 m to 6 m.

The pressure reduction in a capillary tube occurs due to the following two factors:

1. Frictional resistance needs to be overtaken by refrigerant which is offered by the tube walls and it results in some pressure drops.
2. The liquid fluid flashes into wet region as reduced the pressure, the vapour density is less than the density of liquid. So the average density of refrigerant drops it flows in the tube.

Figure: Capillary Tube

Evaporator:

Evaporator is one of the heat exchanger and important component in the refrigeration system. The cooling effect was produced in the refrigeration through the evaporator. In this only, the actual cooling effect takes place in the refrigeration system. The evaporators are the devices that transfer the heat from the substance to be cooled to the refrigerant, therefore removing the heat from the substance

Figure : Evaporator

VI. INSTRUMENTS FITTED TO THE EXPERIMENT:

*Pressure Gauges***:**
A pressure gauge shows the pressure in the system. Most commonly used pressure gauges in Refrigeration installation are

a) Suction (or) Low pressure Gauges.
b) Discharge (or) High pressure Gauges

a) Suction pressure:
It is used on the low-pressure side of the vapour compression refrigeration system. A compound pressure gauge can check pressure both above and below of the atmospheric pressure. A standard pressure gauges dial is graduated to record a pressure range from -30 to 250 psi.

b) Discharge pressure:
The discharge pressure gauge is fitted on the high-pressure side of the vapour compression refrigeration system. It is graduated to record a pressure range from 0 to 500 psi.

Figure: Suction and Discharge pressure gauges

Temperature Indicators (or) Thermocouple:
Thermocouples are used for measuring the temperature of the refrigerant under different conditions in the present experimental work, five Thermocouples are used. Digital temperature indicators are used to find temperatures,

- Evaporator outlet temperature
- Compressor outlet temperature
- Condenser outlet temperature
- De-freezer temperature

Figure : Thermo couples (or) Temperature Indicators.

Tube Cutter:
The copper tube is used in refrigeration system may be cut in two ways:

1. by a tube cutter
2. by a hacksaw

Normally the smaller machines utilize soft copper tubing, this tubing can easily be installed because it can be bent around obstructions and elimination of many elbows is possible. While cutting soft copper tubing an easy and quick method is to apply a tube cutter. The tube to be cut is held in between the “Roller” and “Cutter wheel” and a high pressure is put on the lead screw. Revolve the cutter slowly around the tubing so that the sharp cutting wheel feeds gradually into the tubing, making a clean right angle cut. Hard copper tubing can be cut by a hacksaw when it is held in the flaring block.

Figure: Tube cutter

Flaring tool:

A flaring tool consists of two bars held together by a wing nut and bolt; the bars are provided with holes for various sizes of tubing. A yoke containing the forming die is slipped on the bars and the handle is rotated to produce a flare. This tool finds a wide use because of its simplicity, ease of performing the flaring operation

Figure: Flaring tools

Gas Charging:

After the evacuation, various leakage test like nitrogen and bubble test methods are done to confirm no leakage in the refrigeration system. R290 and blended R290/R134ais inserted to the compressor through service port and allowed to stabilize for 15-20.

Figure: Gas Charging

About R290Refrigerant

Refrigerant R290, or Propane, is a possible replacement of other refrigerants, Due to its low environment impact, in refrigerators. Ozone depletion potential ODP is zero (0) and Global Warming Potential GWP is less than three (<3). It has high COP of the system. The refrigerant R290 has been in use in the past, in refrigerators up to the 1930s and has now again found a wide use in domestic refrigerators and freezers in Europe, especially in Germany, where more than 90% of refrigerators are manufactures using R290 refrigerant. Because, available of Propane (R290) is a possible refrigerant for this application, with good energy efficiency, but with a very different characteristic in several points, which implies the design to be made or adopted for this refrigerant. Special care has to be taken to the flammable.

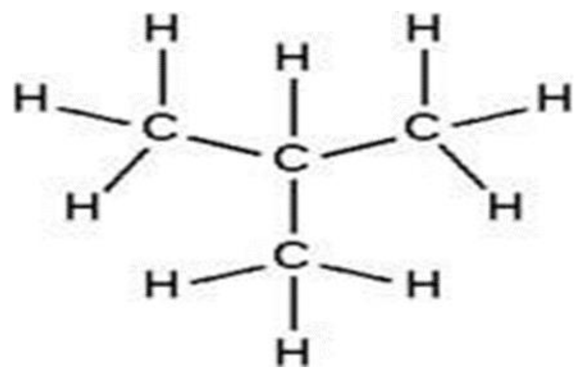


Figure: Structure of propane

Advantages of R290:

- Zero ozone depletion potential
- Excellent thermodynamic properties leading to high energy efficiency.
- low charges allowing smaller heat ex-changers and piping dimensions.

R-134a (1,1,1,2-Tetrafluoroethane):

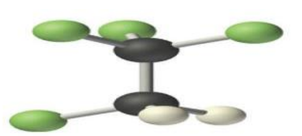
Table 3.9.1 shows the properties of R134a and fig 3.9.1 shows the structure of R134a.

Table 3.9.1: Properties of R134a

Chemical formula	CH_2FCF_3
Molar mass	102.03 g/mol.
Appearance	Colorless gas
Density	0.00425 g/cm3, gas
Melting point	−103.3 °C
Boiling point	−26.3 °C

Experimental Procedure:

1. First R-290 + R-134a, refrigerant is filled in the compressor is fixed and before that nitrogen gas is filled in the compressor and then leak detection test (soap bubble test) conducted and conformed that there are no leakages in the system.
2. Then vacuum is created in another compressor and R290 + R134a refrigerant is charged into the compressor.
3. Temperature and pressure readings are noted by using thermocouples and pressure gauges resp. at required places for normal cycle.
4. After noted the readings R290 refrigerant is discharged from the compressor and vacuum is created by using vacuum pump.
5. Then R290 + R134a refrigerant by mass charge 30g+70g is charged in to the compressor.
6. Temperature and pressure readings are noted by using thermocouples and pressure gauges respectively at required places for normal cycle.
7. And the experiment is repeated for every 15 minutes for getting the states of the thermocouple readings.



Structure of**R134a**

CONCLUSION

Experiment has been performed by comparing the refrigerants R290 & blended mixtures R290/R134a is modified it is observed and increases Coefficient of performance is 0.06. The modified VCR system with the R290 and R134a at condenser outlet. By comparing the refrigerants R290 & blended mixtures R290/R134a is modified system it is observed and decreases of 0.11 in power consumption.

Hence it is recommended that to replace R290 with blended refrigerants. These gives an increase in discharge pressure and refrigeration effect, reduces the work done by compressor and power consumption for refrigerator of 165lit. of capacity with R290 & blended mixtures R290/134a refrigerants.

REFERENCES

[1] Neeraja Upodhya," To study the effect of sub-cooling and diffuser on the COP of vapour compression refrigeration system", International journal of research in aeronautical and mechanical EngineeringISSN:2321-3051 June 2014

[2] Adityaswaroop. "To Improve COP of a Refrigerator Using Diffuser", proceedings of 2017 4th International conference latest trends in engineering, science, humanities and management. Indian federation of united nations association, Qutab institutional area, New Delhi 2017.

[3] R.S. Khurmi, J.K. Gupta, "A Textbook of Refrigeration and Air Conditioning".

[4] R. K. Rajput, "Textbook of Thermal Engineering" and "Refrigeration books".

[5] "Refrigeration and Air Conditioning" by Ramesh Chandra Aroara.

[6] "Thermal Engineering" book by Dr. G. K. Vijayaraghavan.