International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 05 | May 2021 www.irjet.net p-ISSN: 2395-0072

# PERFORMANCE ANALYSIS OF DOMESTIC REFRIGERATOR USING ALTERNATIVE REFRIGERANTS

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**Abstract -** *This work presents the development process of Refrigerator test rig by carried out the performance analysis of domestic refrigerator. The experiment platform which is called refrigerator test rig was developed and performance was calculated which depends on inlet and outlet condition of each components. Hence in this project work, refrigerator test rig have been developed and obtained performance in terms of Refrigeration Capacity, Compressor Work and Coefficient of Performance (COP) by determining two important parameters during operating conditions which are temperature and pressure. In this project work, experiment was carried out by using alternative refrigerants, data were found and compared with each other. Finally the best alternative solution were found for R-134a.*

***Key Words***: Vapour compression Refrigeration System, COP, Refrigeration Effect, Compressor Work.

## INTRODUCTION

What is Refrigeration?

Refrigeration is defined as the procedure of removing heat from a body or enclosed space so that the temperature first lowered and then maintained at level below the temperature of surrounding. The equipment used to maintain the required temperature is called refrigerating equipment.

Types of Refrigeration system

There are two types of refrigeration system

1. Vapour Compression Refrigeration System (VCRS)
2. Vapour Absorption Refrigeration System (VARS)

## PROCESSES

Process 1-2: reversible adiabatic and isentropic compression in compressor.

Process 2-3: constant pressure heat rejection in condenser.

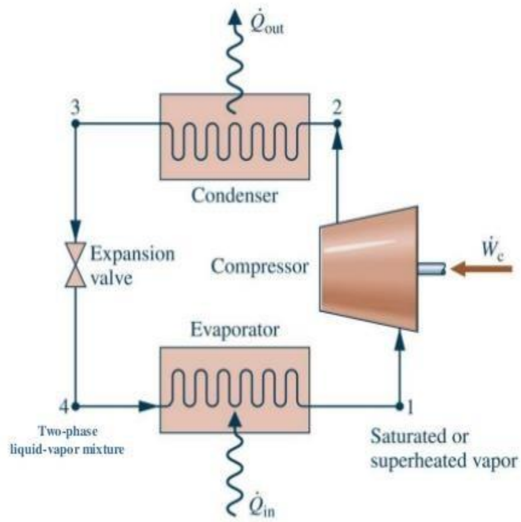
Process 3-4: isenthalpic expansion in expansion device.

Process 4-1: constant pressure heat absorption in evaporators.

## Vapour Compression Refrigeration System (VCRS)

A vapour compression refrigeration system is an improved type of air refrigeration system in which a suitable working substance, termed as refrigerant, is used. It condenses and evaporates at temperatures and pressures close to the atmospheric conditions. The refrigerants usually used for this purpose are ammonia ($NH_3$), carbon dioxide ($CO_2$) and support dioxide ($SO_2$).

Fig. 1.1 Vapour Compression Refrigeration Cycle



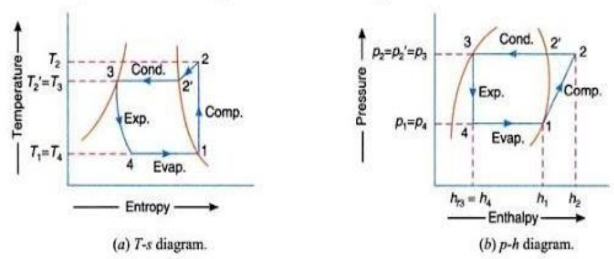




Fig. 1.2 p-h and T-s diagram of VCRS

## COMPONENTS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM

It consists of following essential parts:

1. Compressor

2. Condenser
3. Expansion valve
4. Evaporator

## 1. COMPRESSOR

The low pressure and temperature vapour refrigerant from evaporator is drawn into the compressor through the inlet or suction valve A, where it is compressed to a high pressure and temperature. The high pressure and temperature vapour refrigerant is discharged into the condenser through the discharge valve B.

## 2. CONDENSER

The condenser or cooler consists of coil of pipes in which the high pressure and temperature vapour refrigerant is cooled or condensed. The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water.

## 3. EXPANSION VALVE

Expansion valve is also called throttle valve or refrigerant control valve. The function of expansion valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as pass through the expansion valve, but the greater portion is vaporised in the evaporator at the low pressure and temperature.

## 4. EVAPORATOR

An evaporator consists of coil of pipes in which the liquid refrigerant at low pressure and temperature is evaporated and change into vapour refrigerant at low pressure and temperature. In evaporating, the liquid vapour refrigerant absorbs its latent heat of vaporisation from the medium (air, water or brine) which is to be cooled.

### LITERATURE REVIEW

**Wong wises et al. [2007]** performed the theoretical study on traditional vapour compression refrigeration system with refrigerant mixtures based on HFC134a, HFC152a, HFC32, HC290, HC1270, HC600 and HC600a forvarious ratios and their results are compared with CFC12, CFC22 and CFC134a as possible alternative replacement. Considering the comparison of coefficient of performance (COP) and pressure ratio of tested refrigerants and also the main environmental impacts of ozone layer depletion and global warming, Refrigerant blends of HC290 (40%) + HC600a (60%) and HC290 (20%)+HC1270 (80%) are found to be the most suitable alternatives among refrigerants tested for R12 and R22 respectively. The refrigeration efficiency, coefficient of performance (COP) of the system increases with increasing evaporating temperature for a constant condensing temperature. Similarly Hc22a can be tested for R-134a. **[1]**

**Sattar et al. [2010]** designed a domestic refrigerator to work with R-134a and was used as test unit to determine the possibility of using hydrocarbons and their blends as refrigerants. Pure butane, isobutene and mixture of propane, butane and isobutene were used as refrigerants. The performance of refrigerator using hydrocarbons as refrigerants was investigated and compared with the performance of refrigerator when R-134a was used as a refrigerant. In this experiment, effect of condenser temperature and evaporator temperature on COP, refrigerating effect, Condenser work, work of compression and heat rejection ratio were investigated. After successful investigation on the performance of hydrocarbon and blends of hydrocarbon refrigerants it is found that COP of the system is comparable to R-134a and also energy consumption is similar to R- 134a. **[2]**

**Austin et al. [2011]** had presented the study on refrigerator using mixed refrigerants. The Mixed Refrigerants (hydrocarbons mixtures propane, and isobutene) and compared with the performance of refrigerator with R-134a was used as refrigerant. The effect of condenser temperature and evaporator temperature on COP, refrigerating effect was investigated. The energy consumption of the refrigerator during experiment with mixed refrigerants and R-134a was measured.

**Chavhan et al. [2012]** have presented the study on refrigerator using R134a. R134a is having zero ozone depletion potential (ODP) and almost same thermodynamic properties as R12, but it has a high Global Warming Potential (GWP) of 1300.Hence an alternative for this refrigerant is to be identified. Paper reviews the performance of different environmental friendly refrigerants and their mixtures in different proportions and also observed the effect of working parameters like dimensions of capillary tube, working pressures and working temperatures, which affect the coefficient of performance (COP) of vapor compression refrigeration system.

**Bolaji et al.[2013]**provided comparative experimental steady is carried out of there refrigerator R-152a R-32 & R-134a to replace R-134a R152a & R-32 are new refrigerant having zero ODP & GWP finally, he considered that COP of R-152a 4.7% higher than R-134a & Cop of R32 is 8.5% less than R- 134a. Pull down time is achieved early than R32. Power is considerably reduced with R- 152a than the R-32 R-134a. **[7]**

**Mani et al. [2013],** have analyzed a vapour compression refrigeration system with the new R290/R600a refrigerant mixture as drop-in replacement was conducted and compared with R12 and R134a. The VCRS was initially designed to operate with R12.The results showed that the refrigerant R134a showed slightly lower COP than R12.

**Sarthak, et al [2017]** performed analysis of domestic refrigerator with various alternating refrigerant like R-152a, R-290, R-600a, R-600/290 (50/50), R-436a, R-134a/600 (50/50). Considering the comparison of performance coefficient (COP) and the volumetric efficiency of the refrigerants were found and also the ODP and GWP were tested.

## PROPERTIES OF REFRIGERANTS

- Refrigerants should have the following properties:
- It should have high latent heat of vaporization.
- It should have high critical pressure and temperature.
- It should have low viscosity and dielectric strength.
- It should have low condensing pressure and evaporative pressure slightly higher than the atmospheric pressure. It implies that it should have low pressure ratio.
- It should be non hazardous and non corrosive.
- The leakage finding should be easy.
- It should be cheap.
- It should not be miscible with lubricant oil.

In my project I use the following refrigerants and their properties are given below.

**Table 2.0 Refrigerant Property**

| Refrigerants (category) | Chemical Formula | Normal Boiling point(˚C) | Critical Temperature(˚C) | ODP | GWP | Safety Group |
|---|---|---|---|---|---|---|
| R 134a | $CH_3CH_2F$ | -26.07 | 101.6 | 0 | 1380 | A1 |
| R 290 | $C_3H_8$ | -42.1 | 96.8 | 0 | 20 | A3 |
| R 600a | $C_4H_{10}$ | -11.67 | 135 | 0 | 20 | A3 |

## EXPERIMENTAL SETUP, METHODOLOGY

Table 2.1 Refrigerator Model Details

| Brand | KENSTAR |
|---|---|
| Model name/year | KRC-222SB |
| Freezer Capacity ( litre ) | 80 |
| Fresh Food Compartment Capacity (litre) | 210 L |
| Power Rating | 160W |
| Current Rating | 0.9A |
| Voltage | 220-240V |
| Frequency | 50Hz |
| No of door | Single |
| Compressor | Hermetic – sealed |
| Refrigerant type | R134a |

Thi s Section provides the information about the how the experiment set up and how the test procedure were carried

Fig 1.3 Experimental setup

out during experiment. First the experiment test rig developed from the refrigerator model. To perform the experiment and develop the test ring 210L refrigerator is selected. Fig. shows the line diagram of test ring and connection point of pressure and temperature measurements.

Now From the experiment test rig there are 6 points of temperature measurements and 2 point of pressure measurements. Two point of pressure measurements one point in suction side and another point is in discharge line.

The pressure gauge are used for the pressure measurement so compound gauge is fitted on discharge line due to high pressure and vacuum gauge is fitted on suction line due to low pressure as shown in the fig. Now there five point is temperature measurement so one the point of temperature measurement is in evaporator means in the freezer compartment of refrigerator. One point is for the measurement of food storage cabinet. And point is located on the compressor inlet, compressor outlet, and condenser inlet and condenser outlet. So now for the temperature measurement digital thermometer are used. Ammeter is also used for the current measurement. So this the procedure of the experiment set up.

Fig 1.4 Refrigerant gases and Digital thermometer

Now for the test procedure the evacuation and vacuuming is done by another compressor. And vacuum is done for three hours. This is required for the cleaning of the lines by removing moisture, air and oil. Now after that the refrigerant is charged by the charging system and when the evaporator temperature set at 10$^{o}$c and 1$^{st}$ I charged the R 134a and collected the data like pressure and temperature every 15 minutes during the running the refrigerator. After collecting the data R 134a is removed and refrigerator are charged by another alternative refrigerant like R 290 and R 600a of the different refrigerant and collected the data.

After collecting the experimental data I found the different parameter COP, Refrigerant effect, Compressor power, mass flow rate and then compare this data each other to the refrigerant and find the alternative refrigerant which gives the better performance in compare with R 134a.

## CALCULATION

1. Compressor Work done ($W_C$) = ($h_2 - h_1$)kJ/kg
2. Refrigerant effect Per Kg ($R_E$) = ($h_1 - h_3$) kJ/kg

Where,

$h_1$ = Specific Enthalpy at the inlet of compressor (kJ/kg)

$h_2$ = Specific Enthalpy at the outlet of compressor (kJ/kg)

$h_3$ = Specific Enthalpy at the outlet of condenser (kJ/kg)

$h_4$ = Specific Enthalpy at the inlet of evaporator (kJ/kg)

3. COP = Refrigerant Effect/Compressor Work done

Notes: - Values of h1, h2, hf3, h4 are calculated by using pressure enthalpy diagram related to the various alternative refrigerant during calculation.

## RESULTS AND DISCUSSION

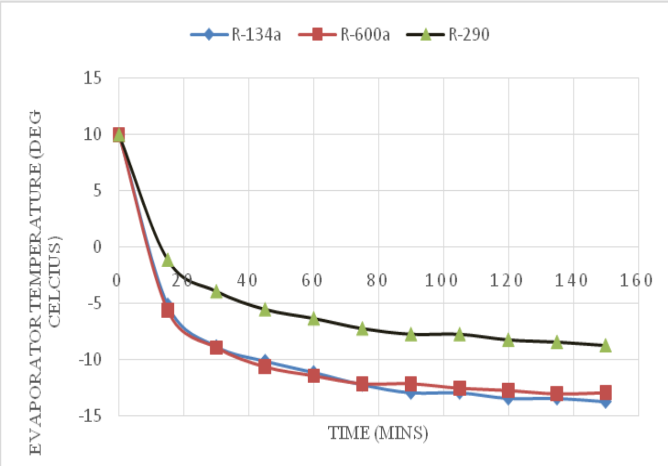



Fig 1.5 Time Vs Evaporator temperature

As shown in the figure at the starting of refrigerator, the evaporating temperature of all refrigerant is set to 10°C and as the refrigerator run the evaporator temperature is decrease and after some time it achieve to constant temperature. During the starting of 15 minute, evaporator temperature drop is high for all refrigerant and among the refrigerants R290 has high temperature. R600a and R 134a has low temperature drop. After 150 minute R600a has a low evaporating temperature.

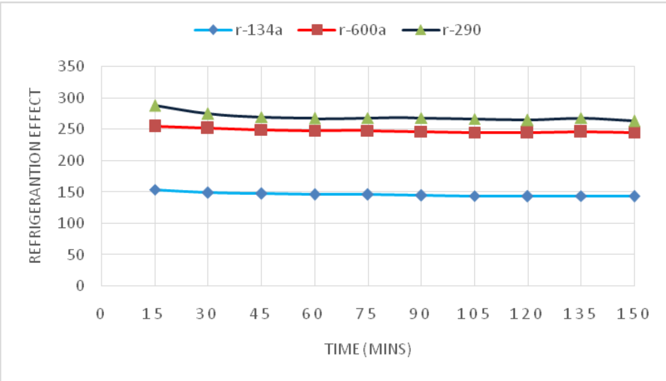



Fig 1.6 Time VS Refrigeration Effect

As shown in the figure at starting of the time the refrigerant is high and then it is start decreasing as the time pass away and one time refrigerant effect is become constant it is due to the setting temperature difference in the cabinet. Now from the figure, it is clear that the refrigerant effect of R290 has high value than any another refrigerant. But at a same time the refrigerant effect is low for R 134a refrigerant. Also From the figure, it is also clear that the after some time, refrigerant effect has a gas constant value.

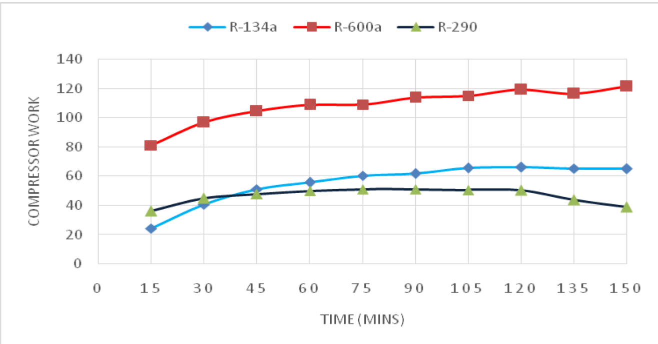



Fig 1.8 Time Vs Compressor work

As shown in figure at the starting of the time the compressor work done is low but as the time increase the compressor work done also increase and after some time it become a constant. The rate of increasing the compressor work done is most of the same for all of the refrigerant. From the fig, it is clear that the compressor work done is low for R134a and R290 than another refrigerants. Now compressor work for refrigerant R600a is high and also work done for refrigerant R600a is high than another refrigerant.

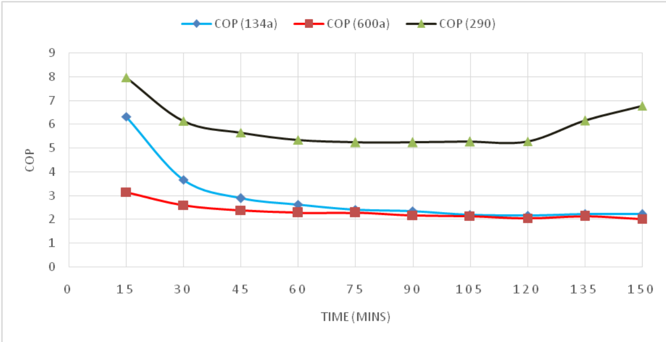



Fig 1.7 Time Vs COP

As shown in figure, the cop at starting of refrigerator is high and R290 has a high COP as the starting and as the time goes the COP all refrigerant is start decreasing and reach the constant value. So from the figure is the clear that the COP of R290 has a high value than another refrigerant and COP of R600a is also near to the COP of R134a. From the figure it is clear that R 290 give the better performance than another alternate refrigerant. So it is possible that the R 290 has a better alternate refrigerant.

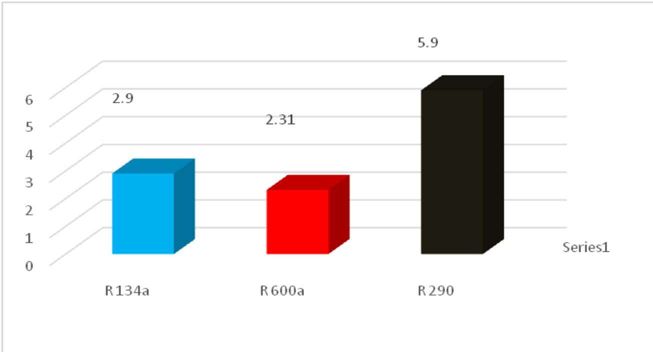



Fig 1.9 Average Coefficient of Performance

From the figure shows the average COP of all refrigerant. From the figure, it is clear that the average COP of the R290 is higher than another refrigerant and also higher than R 134a. While the average COP of R600a is very low. Average COP of R290 is 5.9 and R134a is 2.9 and lowest COP is 2.31 of R600a.

## CONCLUSIONS

In this study performance analysis of the domestic refrigerator carried out by using various alternative refrigerants and blending of refrigerant in order to find the alternate of R 134a. Based on the investigation results, the following conclusion drawn:

Among the refrigerants R290, R600a, has the best desirable environment properties, it has zero Ozone Depletion Potential (ODP) and low global warming potential (GWP).

During the evaporator temperature. Range of 10°C to -15°C. R 290 has a high COP than the R 600a and R 134a. Among the refrigerants R290 has high refrigeration effect and its net refrigerant effect is 269.78 kJ/kg. And the refrigerant R 134a and R 600a has nearly same amount of refrigeration effect.

During the evaporator temperature. Range of 10°C to -15°C the work done by the compressor is low for the R 290 around the 46.39 kJ/kg and the work done by the R 134a is slightly higher around the 55.61 kJ/kg. And for the refrigerant R 600a compressor work done is higher among the all refrigerant.

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