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PERFORMANCE ANALYSIS OF A DOMESTIC REFRIGERATOR USING VARIOUS ALTERNATIVE REFRIGERANT

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Abstract: **This work presents the development process of Refrigerator test ring and then carry- out the performance analysis of domestic refrigerator. The experiment platform which is called refrigerator test ring will be developed from refrigerator model. Performance of refrigerator also depends on inlet and outlet condition of each components. So in this research work refrigerator test ring will be developed and obtain performance of domestic refrigerator in term of Refrigeration Capacity, Compressor Work and Coefficient of Performance (COP) by determining two important parameter during operating condition which are temperature and pressure. So carry out this project I use different alternative refrigerant and find the data and compare the data to each other and then find the alternate of R 134a.**

Keywords: **refrigerator, experiment platform, Refrigeration Capacity, Compressor Work, temperature, pressure.**

1. INTRODUCTION

What is Refrigeration?

Refrigeration is defined as the process 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.

1.1.1 Types of Refrigeration system:

There are two types of refrigeration system

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

1.1.2 VCRS system:

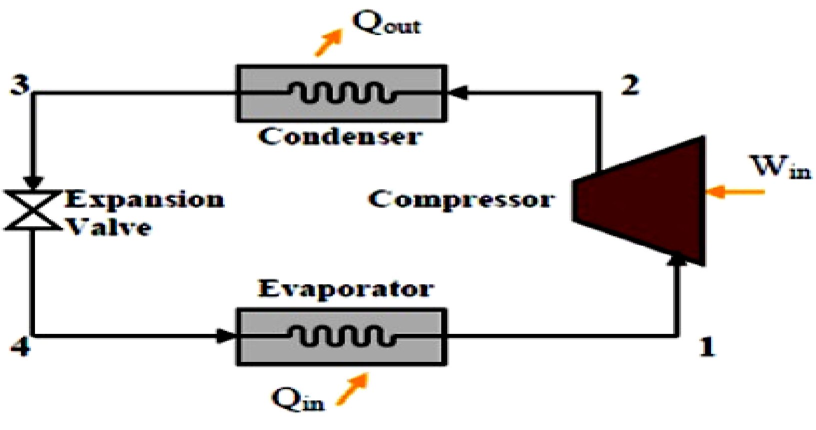

Fig 1: VCRS system

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The above diagram shows the refrigeration circuit. The Main four processes are Evaporation, Compression, Condensation and Expansion.

The process starts with vaporization of the refrigerant in the evaporator. This is complete at point **2**. Compression is used to raise the pressure of the refrigerant, point **3**, so that it can condense at a higher temperature. When all the vapour has condensed, point **4**, the pressure is reduced in an expansion device, and the refrigerant is returned to its original condition **1**.

1.1.3 Components of Refrigeration system:

1. Compressor
2. Condenser
3. Expansion valve
4. Evaporator

1. Compressor

- It compresses the refrigerant. The compressor receives low pressure gas from the evaporator and converts it to high pressure gas. As the gas is compressed, the temperature rises. The hot refrigerant gas then flows to the condenser.

2. Condenser:

- A condenser is a device or unit used to condense a substance from its gaseous to its liquid state, by cooling it. In so doing, the latent heat is given up by the substance, and will transfer to the condenser coolant.

3. Expansion Valve:

- Its function is to meter the amount of refrigerant to be supplied to evaporator and to reduce the pressure up to evaporator pressure such that liquid can vaporise at the evaporator coil.

4. Evaporator:

- An evaporator is used in an air-conditioning system to allow a compressed cooling refrigerant, to evaporate from liquid to gas while absorbing heat in the process. It can also be used to remove water or other liquids from mixtures.

Process 1-2: Isentropic compression of saturated vapour in compressor

Process 2-3: Isobaric heat rejection in condenser

Process 3-4: Isenthalpic expansion of saturated liquid in expansion device

Process 4-1: Isobaric heat extraction in the evaporator

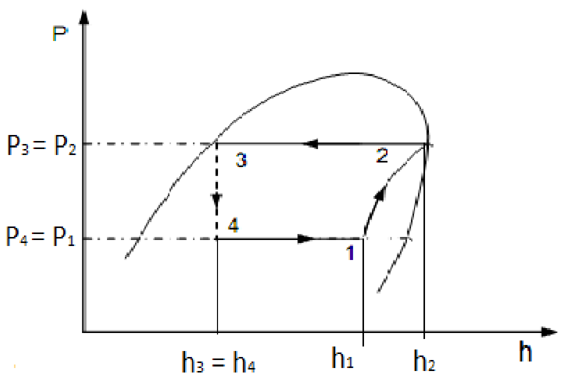

Fig 2: P-h diagram of VCRS system

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Expansion is a constant enthalpy process. It is drawn as a vertical line on the above P-h diagram. No heat is absorbed or rejected during this expansion, the liquid just passes through a valve, like water coming out of a tap. The difference is, that because the liquid is saturated at the start of expansion by the end of the process it is partly vapour. Point 1 is inside the curve and not on the curve as described in the Evaporation process. The refrigerant at the beginning of the vaporization is already partly evaporated. This depends on the shape of the curve, and the start and end pressures.

The Compression process is shown as a curve. It is not a constant enthalpy process. The energy used to compress the vapour turns into heat, and increases its temperature. This tends to raise the temperature of the vapour, making point 3 move further into the superheated part of the diagram as compression progresses. Point 3 is outside the curve as described in the Compression process. This means that before Condensation can start, the vapour has to be cooled down.

Refrigerator:

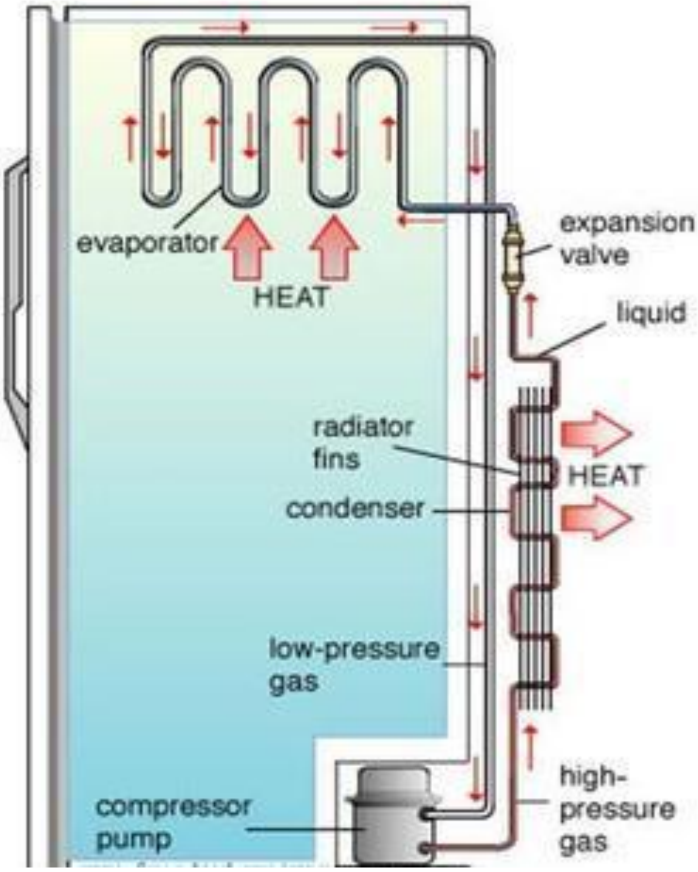

Fig 3: Domestic Refrigerator

1.3.1 Internal Parts of the Domestic Refrigerator:

The internal parts of the refrigerator are ones that carry out actual working of the refrigerator. Some of the internal parts are located at the back of the refrigerator, and some inside the main compartment of the refrigerator.

1) **Refrigerant:** The working substance used to produce refrigeration is called the refrigerant. The refrigerant flows through all the internal parts of the refrigerator. It is the refrigerant that carries out the cooling effect in the evaporator. It absorbs the heat from the substance to be cooled in the evaporator (chillier or freezer) and throws it to the atmosphere via condenser. The refrigerant keeps on recalculating through all the internal parts of the refrigerator in cycle.

2) Compressor: The compressor is located at the back of the refrigerator and in the bottom area. The compressor sucks the refrigerant from the evaporator and discharges it at high pressure and temperature. The compressor is driven by the electric motor and it is the major power consuming devise of the refrigerator. In most of the refrigerator reciprocating and hermitically sealed compressor are used.

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3) Condenser: In refrigerator air-cooled condenser is used since, the constriction of air-cooled condenser is very simple. The condenser is the thin coil of copper tubing located at the back of the refrigerator. The refrigerant from the compressor enters the condenser where it is cooled by the atmospheric air thus losing heat absorbed by it in the evaporator and the compressor. To increase the heat transfer rate of the condenser, it is finned externally.

4) Expansion valve or the capillary: The refrigerant leaving the condenser enters the expansion devise, which is the capillary tube in case of the domestic refrigerators. The capillary is the thin copper tubing made up of number of turns of the copper coil. When the refrigerant is passed through the capillary its pressure and temperature drops down suddenly. And it is a constant enthalpy process.

5) Evaporator or freezer: The refrigerant at very low pressure and temperature enters the evaporator or the freezer. The evaporator is the heat exchanger made up of several turns of copper or aluminium tubing. In domestic refrigerators the plate types of evaporator is used as shown in the figure above. The refrigerant absorbs the heat from the substance to be cooled in the evaporator, gets evaporated and it then sucked by the compressor. This cycle keeps on repeating.

6) Temperature control devise or thermostat: To control the temperature inside the refrigerator there is thermostat, whose sensor is connected to the evaporator. The thermostat setting can be done by the round knob inside the refrigerator compartment. When the set temperature is reached inside the refrigerator the thermostat stops the electric supply to the compressor and compressor stops and when the temperature falls below certain level it restarts the supply to the compressor.

7) Defrost system: The defrost system of the refrigerator helps removing the excess ice from the surface of the evaporator. The defrost system can be operated manually by the thermostat button or there is automatic system comprising of the electric heater and the timer.

Fig 4: External Parts of Domestic Refrigerator

Now let us see the external parts of the refrigerator.

The external parts of the refrigerator are: freezer compartment, thermostat control, refrigerator compartment, crisper, refrigerator door compartment, light switch etc.

External Visible Parts of the Refrigerator

1) Freezer compartment: The food items that are to be kept at the freezing temperature are stored in the freezer compartment. The temperature here is below zero degree. Celsius so the water and many other fluids freeze in this compartment. If you want to make ice- cream, ice, freeze the food etc. they have to be kept in the freezer compartment

2) Thermostat control: The thermostat control comprises of the round knob with the temperature scale that help setting the required temperature inside the refrigerator. Proper Setting of the thermostat as per the requirements can help saving lots of refrigerator electricity bills.

3) Refrigerator compartment: The refrigerator compartment is the biggest part of the refrigerator. Here all the food items that are to be maintained at temperature above zero degree Celsius but in cooled condition are kept. The refrigerator compartment can be divided into number of smaller shelves like meat keeper, and others as per the requirement.

4) Crisper: The highest temperature in the refrigerator compartment is maintained in the crisper. Here one can keep the food items that can remain fresh even at the medium temperature like fruits, vegetables, etc.

5) Refrigerator door compartment: There are number of smaller subsections in the refrigerator main door compartment. Some of these are egg compartment, butter, dairy, etc.

6) Switch: This is the small button that operates the small light inside the refrigerator. As soon the door of the refrigerator opens, this switch supplies electricity to the bulb and it starts, while when the door is closed the light from the bulb stops. This helps in starting the internal bulb only when required.

Properties of refrigerants:

Refrigerant should be required following properties :

- It should be non-toxic, non-flammable and non-corrosive.
- It should have low condensing pressure and the evaporative pressure slightly above the atmospheric pressure. It implies that it should low pressure ratio.
- It should have high latent heat of vaporization
- It should have high critical pressures and temperature.
- It should have low boiling point and freezing point.
- It should have low viscosity and die-electric strength.
- Specific volume should be suitable to the application.
- It should not be miscible with lubricating oil.
- The leak detection should be easy.
- It should be cheap.

Chemical refrigerants are assigned an R number which is determined systematically according to molecular structure.

In my project I use the following refrigerant and also blend of different refrigerant

1. R-134a
2. R-600
3. R-290
4. R-152
5. R-600a
6. R-436a

7. R600/R 290(50/50)

8. R134/R290(50/50)

9. R134/R600(50/50)

Table 1: Refrigerant Property

Refrigerant (category)	Chemical Formula	Normal boiling point	Critical Temperature(^oC)	ODP	GWP	Safety group
R 134a	CF_3CH_2F	-26.07	101.6	0	1380	A1
R 152a	CH_3CHF_2	-24.2	113.5	0	20	A1
R 290	C_3H_8	-42.1	96.8	0	20	A3
R 600	C_4H_{10}	-0.56	153	0	20	A3
R 600a	$(CH_3)_3CH$	-11.67	135	0	20	A3
R600/290(50/50)	$C_4H_{10}+C_3H_8$	-21.33	124.9	0	20	A3
R134a/R290(50/50)	$CF_3CH_2F+ C_3H_8$	-34.07	99.2	0	20	A3
R 436a		-51.6	78.1	0	600	A3
R134a/R600(50/50)	$CF_3CH_2F+ C_4H_{10}$	-13.31	133.25	0	20	A3

2. EXPERIMENT SET UP, METHODOLOGY

Refrigerator Model Details:

Table 2: specification refrigerator

Brand	Whirlpool
Model name/year	DC -5256/2012
Freezer Capacity (liter)	80
Fresh Food Compartment Capacity (liter)	230
Power Rating	160W
Current Rating	0.9A
Voltage	220-240V
Frequency	50Hz
No of door	Single
Compressor	Hermetic - sealed
Refrigerant type	R134a

1. Cabinet:

-Internal volume= 0.025 cubic meter

2. Evaporator:

-Mode of heat transfer= Free convection and conduction.

-Linear length of coil or tube= 15.5 feet= 4.5 meter

-Internal and external diameter of the tube= 6mm and 7mm or 0.00515m and 0.00625m respectively.

-Material of coil or tube= copper tube.

3. Condenser:

- Mode of heat transfer= Free convection

- Linear length of the coil= 4.2m

-Internal and external diameter of the tube= 3.43 mm and 4.13 mm or 0.004m and 0.004m respectively.

- Material of the tube= steel and wire tube.

4. Compressor:

LG MA 42LFJG 1PH 220-240V, 50HZ

5. Expansion device = Capillary tube

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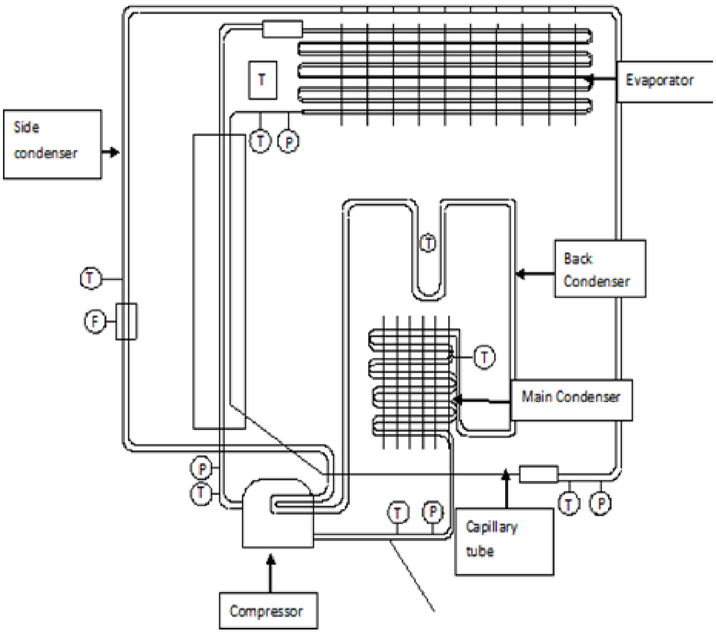

Figure 5: Line diagram of set up

Figure 6: Overall experiment Set Up

Experiment set up & procedure:

This Section provides the information about the how I was developed the experiment set up and how I will carry out the test procedure the during experiment. First the experiment test ring developed from the refrigerator model. To perform the experiment and develop the test ring 230L refrigerator is selected. and Fig. shows the line diagram of test ring and connection point of pressure and temperature measurement.

Now from the experiment test ring there 6 point of temperature measurement and 2 point of pressure measurement. Two point of pressure measurement one of the 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 pointis 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, 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.

Now for the test procedure the evacuation and vacuuming is done by the another compressor. And vacuum is done up to the 25in/hg. 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 temp. set at 10^{o}c and 1st I charged the R 134a and collected the data like pressure and temperature every 15 minutes during the running the refrigerator and also collected the data various evaporator temperature. After collecting the data R 134a is removed and refrigerator are charged by another alternative refrigerant like R 290, R 600, R 152a and mixture of the different refrigerant and collected the data. After collecting the experimental data I found different parameter like COP, Refrigerant effect, Compressor power, Volumetric cooling capacity, mass flow rate , compressor power per ton, compression ratio etc. 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.

So in this way I will be found the best alternative of R 134a

Now during the Experiment following tables for different Refrigerants are preapared by determining pressure and temperature :

Table 3: Experimental Data Of R 134a

Time Reading Taken	Compress-or inlet Pressure P_1 (MPa)	Compress-or outlet Pressure P_3 (MPa)	Compressor inlet Temp T_1 ˚C	Compressor outlet Temp T_2 ˚C	Condenser inlet Temp T_3 ◦C	Condenser outlet Temp T_4 ˚C	Evaporator Tempature
10:30	0.4146	1.7628	31.2	42.5	37.7	28.1	10
10:45	0.2006	1.1301	31	47.9	41.9	28.9	-9.9
11:00	0.1680	1.1493	30	52.3	45.6	27.5	-15
11:15	0.1416	1.1513	30.8	57.9	48.9	27	-18.5
11:30	0.1199	1.1632	30.2	60.7	53.2	25.7	-23.7
11:45	0.0907	1.1832	29	63.9	55.8	25	-27.8
12:00	0.8138	1.1903	28.7	65.11	57.3	24.6	-29.6
12:15	0.8213	1.1903	27	66	57.8	24	-30.5
12:30	0.0622	1.1923	27	68.44	57.7	23.1	-33.1
12:45	0.0679	1.1923	26.9	68	57.6	23	-34

Table 4: Experimental data of R 290

Time Reading Taken	Compressor inlet Pressure P_1(MPa)	Compressor outlet Pressure P_3 bar	Compressor inlet Temp T_1 ˚C	Compresso r outlet Temp T_2 ˚C	Condenser inlet Temp T_3 ◦C	Condenser outlet Temp T_4 ˚C	Evaporator Tempature
10:30	0.6366	1.8064	31.5	41.1	35.6	30.9	10
10:45	0.2626	1.7780	31	52.9	41.3	32.7	-19.3
11:00	0.21119	1.6892	29.4	59.8	47.4	34.5	-24.8
11:15	0.2213	1.6547	28.8	64.9	53.3	37	-25.7
11:30	0.19144	1.6064	28	67.3	56.4	37.9	-27.7
11:45	0.15303	1.6133	27.3	71.5	58.9	38.1	-28.7
12:00	0.15502	1.57200	27	73.3	59.8	38.6	-31
12:15	0.1495	1.5690	26.8	74.5	60.5	39.4	-33.5
12:30	0.1492	1.5645	23.9	75.9	61.1	40.4	-34
1:00	0.1392	1.5723	23	76	61.9	41	-34

Table 5: Experimental data of R 290/600

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Time Reading Taken	Compressor inlet Pressure P_1 MPa	Compressor outlet Pressure P_2 MPa	Compressor inlet Temp T_1 °C	Compressor outlet Temp T_2 °C	Condenser inlet Temp T_3 °C	Condenser outlet Temp T_4 °C	Evaporator Tempature
10:30	0.3892	1.4265	30.1	40.1	33.3	21	10
10:45	0.1789	1.188	29.2	52.9	40.1	20.3	-14.7
11:00	0.15923	1.6121	29	59.8	44.3	19	-18.8
11:15	0.1486	1.0863	30	64.9	49,3	18.8	-20.1
11:30	0.1369	1.0523	28.5	68.1	52,3	18	-23.5
11:45	0.1152	1.0251	27	70.8	55.3	17	-26.5
12:00	0.1076	1.0183	29.8	73.5	56	17.1	-28.5
12:15	0.09858	0.9997	27	75.1	56.6	17	-30.2
12:30	0.09858	0.9843	26.7	76.2	57	16.9	-30.2
12:45	0.09802	0.9843	26	76	57.2	16.5	-30

Table 6: Experimental data of R 600

Time Reading Taken	Evaporator inlet Pressure P_1 MPa	Condenser outlet Pressure P_3 MPa	Compressor inlet Temp T_1 °C	Compressor outlet Temp T_2 °C	Condenser inlet Temp T_3 °C	Condenser outlet Temp T_4 °C	Evaporator Tempature
10:30	0.8587	0.14185	30.1	41.5	33.3	21	10
10:45	0.8090	0.10323	29.2	47.7	40.1	22.3	-14.7
11:00	0.78702	0.085090.	29	54.7	44.3	24	-18.8
11:15	0.76402	0.06853	30	60.1	49,3	25.5	-20.1
11:30	0.7191	0.05636	28.5	63	52,3	27	-23.5
11:45	0.6999	0.05353	27	65.8	55.3	26	-26.5
12:00	0.6999	0.04521	29.8	67	56	25.6	-28.5
12:15	0.6384	0.03591	27	68.8	56.6	24.9	-30.2
12:30	0.6182	0.03391	26.7	70	57	25.2	-30.2
12:45	0.6182	0.03391	26	70.9	57.2	26	-30

Table 7: Experimental Data Of R 134a/R 290

Time Reading Taken	Compress-or inlet Pressure P_1 (MPa)	Compress-or outlet Pressure P_3 (MPa)	Compressor inlet Temp T_1 °C	Compressor outlet Temp T_2 °C	Condenser inlet Temp T_3 °C	Condenser outlet Temp T_4 °C	Evaporator Tempature
10:30	2.1168	0.5256	30.2	40.1	35.9	31.4	10
10:45	2.032	0.2470	31	49.9	39.4	32.4	-13.2
11:00	1.9367	0.1971	29.3	55.7	44.1	33	-19.1
11:15	1.8931	0.1457	29.7	58.9	46.3	33.1	-26.8
11:30	1.8000	0.1370	28	62.4	50.4	32	-28.1
11:45	1.7802	0.1260	27.1	66.7	53.8	31.7	-30.2
12:00	1.7194	0.1096	26.5	69.1	57.9	30	-32.1
12:15	1.6986	0.1040	25	70.6	58.9	29.4	-33.9
12:30	1.6986	0.1040	25.1	73.6	58	29	-33.9

Table 8: Experimental Data Of R600a

Time Reading Taken	Compress-or inlet Pressure P_1 (MPa)	Compress-or outlet Pressure P_3 (MPa)	Compressor inlet Temp T_1 °C	Compressor outlet Temp T_2 °C	Condenser inlet Temp T_3 °C	Condenser outlet Temp T_4 °C	Evaporator Tempature
10:30	0.9738	0.2206	29.9	39.7	34.1	30.4	10
10:45	0.8618	0.1013	30.1	50.4	40.6	30	-13.7
11:00	0.82773	0.0851	28.8	55.8	45.6	31.5	-16.3
11:15	0.8066	0.0724	27.5	58.9	46.8	29	-20.2

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11:30	0.7928	0.0668	27	60.1	49.6	27.9	-23.4
11:45	0.7584	0.0584	26.9	63.7	51.4	26.9	-25.1
12:00	0.7574	0.0574	26	66.9	52.8	28.6	-26
12:15	0.7574	0.0574	25.5	70.1	54.9	28	-26
12:30	0.7574	0.0574	26	71	56.8	27.9	-26

Table 9: Experimental Data Of R152a

Time Reading Taken	Compress-or inlet Pressure P_1 (MPa)	Compress-or outlet Pressure P_3 (MPa)	Compressor inlet Temp T_1 °C	Compressor outlet Temp T_2 °C	Condenser inlet Temp T_3 °C	Condenser outlet Temp T_4 °C	Evaporator Tempature
10:30	0.1815	1.8840	30.9	41.5	35.9	28.5	10
10:45	0.1605	1.4310	31	49.7	39.1	28.9	-12.5
11:00	0.1343	1.4538	29.5	55.2	44.5	27	-18.9
11:15	0.1101	1.4763	28.1	58.3	47.7	26.5	-23.1
11:30	0.0928	1.5007	27.5	60.9	50.9	26.1	-26.8
11:45	0.0849	1.5132	27.9	64.7	52.5	25	-28
12:00	0.0771	1.5323	27	68.9	55.7	25.5	-30.9
12:15	0.0781	1.5535	26.8	71.5	56.9	23.6	-34.1
12:30	0.0781	1.5535	26.5	71.3	56.8	23.4	-34.1

Table 10: Experimental Data Of R1341a/R600(50/50)

Time Reading Taken	Compress-or inlet Pressure P_1 (MPa)	Compress-or outlet Pressure P_2 (MPa)	Compressor inlet Temp T_1 °C	Compressor outlet Temp T_2 °C	Condenser inlet Temp T_3 °C	Condenser outlet Temp T_4 °C	Evaporator Tempature
10:30	0.2813	1.5442	29.9	40.9	35.2	29.4	10
10:45	0.2240	1.1220	30.5	48.1	40.1	31.3	-13.3
11:00	0.0731	1.0863	29	53.9	43.7	28.3	-18.4
11:15	0.0686	1.0728	28.1	56.9	45.8	27.4	-21.9
11:30	0.0593	1.0555	28	60.8	51.3	28	-23.8
11:45	0.0553	1.0455	27.5	63.9	53.9	26.1	-27.5
12:00	0.0513	1.0183	26.9	67.9	55.5	25.8	-29.2
12:15	0.0463	0.9843	26	70.1	56.2	25	-30.3
12:30	0.0463	0.9843	25.8	70	56.3	25.1	-30.3

Table 11: Experimental Data Of R436a

Time Reading Taken	Compress-or inlet Pressure P_1 (MPa)	Compress-or outlet Pressure P_2 (MPa)	Compressor inlet Temp T_1 °C	Compressor outlet Temp T_2 °C	Condenser inlet Temp T_3 °C	Condenser outlet Temp T_4 °C	Evaporator Tempature
10:30	0.4535	1.3438	31.1	41.1	36.7	31.3	10
10:45	0.2622	1.3100	29.2	50.9	41.4	32.6	-12.5
11:00	0.1616	1.1832	28.1	55.8	46.3	33.9	-18.8
11:15	0.1234	1.1612	27.7	60.1	48.9	36.1	-19.8
11:30	0.0935	1.0825	27	65.9	52.3	37.8	-22.4
11:45	0.0808	1.0523	26.1	70.1	54.8	38.8	-25.1
12:00	0.0703	1.0182	25	72.9	55.9	39.1	-26.5
12:15	0.0651	0.9779	25.2	73.9	56.8	40.2	-31
12:30	0.0651	0.9779	24.9	74	56.7	40.6	-31

So in this way during the experiment I develop the table by measuring compressor inlet, compressor outlet pressure , Discharge pressure and condenser inlet and outlet temp. and evaporator temperature.

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And using this data I found refrigerant effect, Compressor work done, Compressor ratio, Mass floe rate, COP and Compressor Power and VRC by using the following equation and PH diagram of refrigerants and after calculating reading table developed in next section.

Calculation:

1. Compressor Work done (w) = (h2 – h1) KJ/Kg

2. Refrigerant effect Per Kg (RE) = (h1 – h3) 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. $\text{COP} = \frac{\text{Refrigerant effect}}{\text{Compressor work done}}$

4. Mass flow rate = $\frac{3.517}{\text{RE}}$

5. Compression ratio = $\frac{\text{Discharge pressure}}{\text{Suction pressure}}$

6. $\text{Compressor power per ton} = \text{Mass flow rate} \times \text{Compressor work done}$

7. $\text{Volumetric refrigerant efficincy} = \frac{\text{RE}}{Vg_1} = \frac{113.34}{0.04944} = 2942.15\text{kg/m}^3$

Notes:- Values of h_1, h_2, hf_3, h_4 are calculated by using pressure enthalpy diagram related to the various alternative refrigerant during calculation.

Now using the above equation we find the data n develop the table as follows:

Table 12: Calculation Reading of R 134a

Time	Refrigerant-effect per kg (KJ/Kg)	Compressor work done (kJ/kg)	COP	Compression Ratio	Compressor power per ton (kW)	Volumetric cooling capacity(kg/m^3)
10:30	113.54	22.82	5.05	4.25	0.6153	2296.52
10:45	130.23	28.45	4.91	5.63	0.7681	1400.05
11:00	127.01	31.21	4.09	6.84	0.8426	1168.97
11:15	124.68	31.56	3.93	8.13	0.8836	940.97
11:30	120.92	34.48	3.61	9.69	0.9920	825.97
11:45	117.29	35.11	3.35	13.04	1.0533	693.43
12:00	113.03	37.03	3.02	14.62	1.1109	628.43
12:15	112.03	37.13	3.02	14.49	1.1209	568.63
12:30	110.36	39.73	2.79	18.85	1.2316	534.06
12:45	110.36	39.73	2.79	18.85	1.2316	534.06

- Now the Average COP of Refrigerator = 3.65
- Net mass flow rate = 0.024 Kg/s
- Net Refrigerant effect = 117.98 KJ/Kg

Refrigerator capacity in tonnes = $\frac{\text{Mass flow rate x RE x 3600}}{14000} = 0.7887$

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Table 13: Calculation Reading of R 290a

Time	Refrigerant-effect per kg (KJ/Kg)	Compressor work done (Kj/kg)	Compressor ratio	Compressor power in ton	COP	Volumetric cooling capacity (kg/m^{3})
10:30	248.7	36.08	2.83	0.5183	6.89	3290.15
10:45	216.9	68.52	6.72	1.1123	3.51	1197.15
11:00	216.47	73.21	7.99	1.1136	2.95	1038.89
11:15	215.08	73.74	8.22	1.1973	2.92	944.37
11:30	213.97	75.97	9.00	1.2155	2.81	752.37
11:45	218.69	78.01	9.38	1.2481	2.42	843.01
12:00	213.84	80.11	10.05	1.2827	2.66	768.65
12:15	206.15	87.95	10.14	1.4995	2.34	685.86
12:30	202.18	88.01	10.72	1.506	2.32	643.06
12:43	202.18	88.02	10.77	1.506	2.30	643.06

- Now the Average COP of Refrigerator = 3.11
- Net mass flow rate = 0.016 Kg/s
- Net Refrigerant effect = 215.41 KJ/Kg

$$\text{Refrigerator capacity in tonnes} = \frac{\text{Mass flow rate x RE x 3600}}{14000} = 0.8867$$

Table 14: Calculation Reading of R 290a/600

Time	Refrigerant-effect per kg (KJ/Kg)	Compressor work done (KW)	Compressor ratio	Compressor power per ton (kW)	COP	Volumetric cooling capacity (kg/m^{3})
10:30	210.675	73.87	2.93	1.2341	2.63	1229.54
10:45	222.492	77.32	7.29	1.2523	2.67	489.84
11:00	215.01	85.1	7.29	1.3692	2.53	453.84
11:15	210.98	97.84	6.47	1.4676	2.15	410.94
11:30	210.5	98.72	8.49	1.4823	2.13	360.15
11:45	203.31	102.015	8.81	1.6485	1.99	335.15
12:00	202.075	107.05	9.62	1.7122	1.88	325.20
12:15	201.13	107.93	10.16	1.8882	1.86	312.41
12:30	201.95	108.19	11.12	1.8392	1.86	304.23
12:45	201.95	108.19	11.12	1.8329	1.86	304.23

Now the Average COP of Refrigerator = 2.15

- Net mass flow rate = 0.014 Kg/s
- Net Refrigerant effect = 208.003 KJ/Kg

$$\text{Refrigerator capacity in tonnes} = \frac{\text{Mass flow rate x RE x 3600}}{14000} = 0.7915$$

Table 15: Calculation Reading of R 600

Time	Refrigerant-effect per kg (KJ/Kg)	Compressor work done (KW)	Compressor Power per ton (kW)	Compressor ratio	COP	Volumetric cooling capacity (kg/m^{3})
10:30	218.49	87.22	1.4039	6.05	2.50	933.96
10:45	209.21	98.5	1.6509	7.83	2.19	576.23
11:15	199.11	109.4	1.9225	9.24	1.82	458.23
11:00	195.09	111.59	2.0116	11.82	1.74	358.52
11:30	201.63	113	1.9710	12.77	1.78	318.52

11:45	197.59	119.14	2.1206	16.24	1.65	252.53
12:00	195.59	120.21	2.1207	17.17	1.62	201.82
12:15	194.88	120.88	2.1847	18.23	1.62	197.004
12:30	194.88	120.88	2.1847	18.23	1.61	197.004
12:43	194.88	120.88	21847	18.23	1.61	197.004

- Now the Average COP of Refrigerator = 1.81
- Net mass flow rate = 0.017 Kg/s
- Net Refrigerant effect = 200.13 KJ/Kg

$$\text{Refrigerator capacity in tonnes} = \frac{\text{Mass flow rate x RE x 3600}}{14000} = 0.8807$$

Table 16: Calculation Reading of R134a/R290

Time	Refrigerant-effect per kg (KJ/Kg)	Compressor work done (KJ/Kg)	Compressor Power per ton (kW)	Compressor ratio	COP	Volumetric cooling capacity (kg/m^{3})
10:30	158.783	33.01	0.7311	4.027	4.81	2592.54
10:45	141.71	51.70	1.2820	8.22	2.74	1109.23
11:15	143.23	56.52	1.3878	9.82	2.53	962.340
11:00	141.558	62.42	1.4980	12.61	2.26	684.97
11:30	143.69	62.84	1.5081	13.13	2.29	642.60
11:45	146.16	63.04	1.5129	14.12	2.21	603.24
12:00	142.95	65.93	1.5823	15.67	2.18	447.37
12:15	142.24	67.62	1.6224	17.19	2.10	383.04
12:30	142.24	67.62	1.6224	17.19	2.10	383.04
12:43	142.24	67.62	1.6224	17.19	2.10	383.04

- Now the Average COP of Refrigerator = 2.53
- Net mass flow rate = 0.024 Kg/s
- Net Refrigerant effect = 151.84 KJ/Kg

$$\text{Refrigerator capacity in tonnes} = \frac{\text{Mass flow rate x RE x 3600}}{14000} = 0.9352$$

Table 17: Calculation Reading of R 600a

Time	Refrigerant-effect per kg (KJ/Kg)	Compressor work done (KJ/Kg)	Compressor Power per ton (kW)	Compressor ratio	COP	Volumetric cooling capacity (kg/m^{3})
10:30	205.49	71.94	1.2229	4.41	2.85	1205.64
10:45	187.94	96.93	1.7447	8.50	1.92	531.24
11:00	199.01	100.15	1.7025	9.72	1.99	638.47
11:15	186.68	102.57	1.8392	11.12	1.82	385.15
11:30	185.18	103.87	1.8696	12.18	1.78	353.80
11:45	185.01	104.01	1.8791	13.02	1.77	213.24
12:00	185.01	104.01	1.8791	14.18	1.77	213.24
12:15	185.01	104.01	1.8791	14.18	1.77	213.24
12:30	185.01	104.01	1.8791	14.18	1.77	213.24
12:45	185.01	104.01	1.8791	14.18	1.77	213.24

- Now the Average COP of Refrigerator = 1.92
- Net mass flow rate = 0.018 Kg/s
- Net Refrigerant effect = 170.26 KJ/Kg

$$\text{Refrigerator capacity in tonnes} = \frac{\text{Mass flow rate x RE x 3600}}{14000} = 0.7880$$

Table 18: Calculation Reading of R 152a

Time	Refrigerant-effect per kg (KJ/Kg)	Compressor work done (KJ/Kg)	Compressor Power per ton (kW)	Compressor ratio	COP	Volumetric cooling capacity (kg/m$^{3)}$
10:30	182.62	28.59	0.5432	5.01	6.39	2268.03
10:45	192.28	40.22	0.7239	8.91	4.75	1044.20
11:00	185.92	45.18	0.8132	11.06	4.11	650.22
11:15	182.33	47.97	0.9114	13.40	3.80	549.18
11:30	177.14	51.6	0.9804	16.17	3.44	503.12
11:45	175.96	52.88	1.0047	17.19	3.32	418.39
12:00	172.1	55.89	1.0619	19.87	3.07	387.40
12:15	169.98	57.10	1.0849	20.02	2.97	322.01
12:30	169.96	57.12	1.0849	20.12	2.97	322.01
12:45	169.96	57.10	1.0849	20.12	2.97	322.01

- Now the Average COP of Refrigerator = 3.77
- Net mass flow rate = 0.019 Kg/s
- Net Refrigerant effect = 177.82 KJ/Kg

$$\text{Refrigerator capacity in tonnes} = \frac{\text{Mass flow rate x RE x 3600}}{14000} = 0.8688$$

Table 19: Calculation Reading of R134a/R600(50/50)

Time	Refrigerant-effect per kg (KJ/Kg)	Compressor work done (KJ/Kg)	Compressor Power per ton (kW)	Compressor ratio	COP	Volumetric cooling capacity (kg/m$^{3)}$
10:30	160.025	61.39	1.3449	5.48	2.60	1038.71
10:45	133.26	88.98	2.3475	5.44	1.49	746.87
11:00	134.59	91.38	2.3878	14.86	1.47	651.98
11:15	133.35	92.78	2.4122	15.63	1.43	500.01
11:30	132.12	94.89	2.4671	17.61	1.39	486.13
11:45	131.88	95.89	2.3972	18.89	1.37	453.01
12:00	131.32	95.99	2.3997	19.84	1.37	370.11
12:15	132.33	97.55	2.5925	20.84	1.35	312.42
12:30	132.11	97.65	2.5925	20.86	1.35	303.21
12:45	132.11	97.65	2.5935	20.28	1.35	302.21

- Now the Average COP of Refrigerator = 1.52
- Net mass flow rate = 0.025 Kg/s
- Net Refrigerant effect = 135.29 KJ/Kg

$$\text{Refrigerator capacity in tonnes} = \frac{\text{Mass flow rate x RE x 3600}}{14000} = 0.869$$

Table 20: Calculation Reading of R 436a

Time	Refrigerant-effect per kg (KJ/Kg)	Compressor work done (KJ/Kg)	Compressor Power per ton (kW)	Compressor ratio	COP	Volumetric cooling capacity (kg/m$^{3)}$
10:30	228.77	55.24	0.8495	2.96	4.13	1978.60

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10:45	222.23	63.30	0.9495	4.99	3.50	1038.15
11:00	214.95	79.32	1.2974	7.32	2.70	845.88
11:15	213.41	83.38	1.3741	9.41	2.55	701.98
11:30	221.25	83.88	1.3997	11.35	2.76	614.6
11:45	201.91	87.66	1.5269	13.023	2.40	523.90
12:00	210.64	88.43	1.4740	14.14	2.38	450.61
12:15	209.1	90.38	1.5201	15.01	2.31	427.97
12:30	209.1	90.38	1.5201	15.01	2.31	427.76
12:45	209.1	90.38	1.5201	15.01	2.31	427.76

- Now the Average COP of Refrigerator = 2.73
- Net mass flow rate = 0.016 Kg/s
- Net Refrigerant effect = 214.04 KJ/Kg

$$\text{Refrigerator capacity in tonnes} = \frac{\text{Mass flow rate x RE x 3600}}{14000} = 0.880$$

3. RESULT AND DISCUSSION

- In this chapter I discuss the and carry out the comparison of the various refrigerant which I use in my project work and after I go for result and find best alternative refrigerant of R 134a

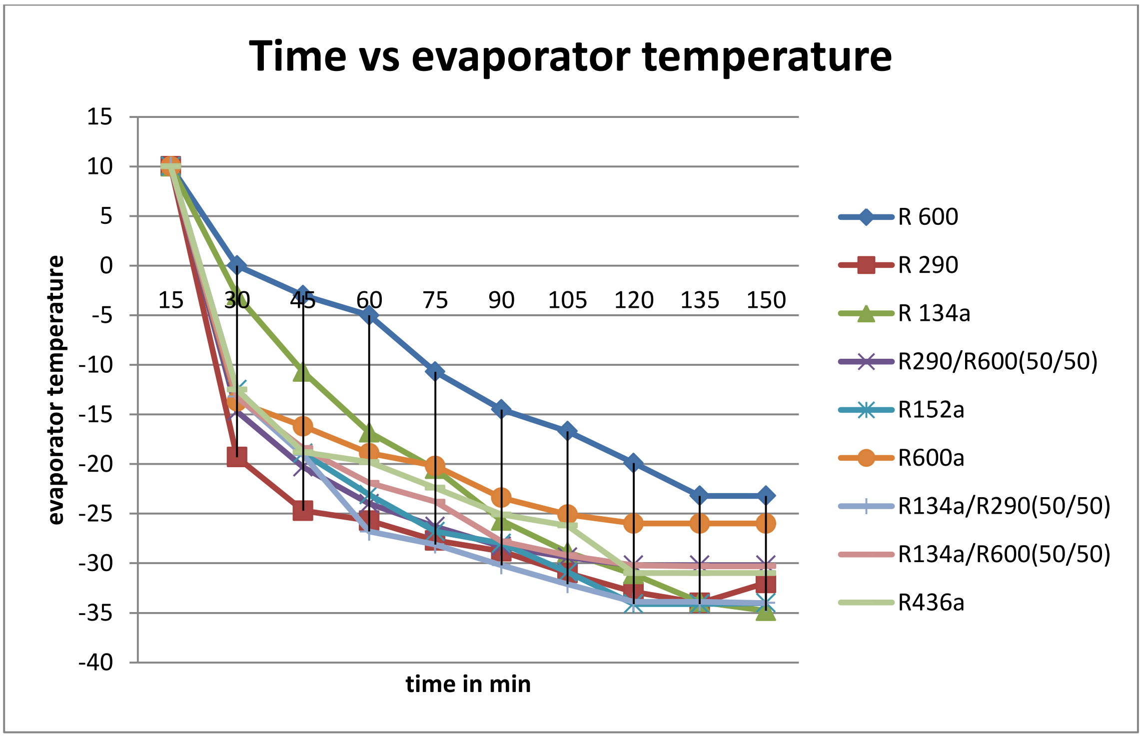

Fig 7: Time VS evaporator temperature

As shown in the fig. at the staring of refrigerator the evaporating temp. of all refrigerant is set to 10^{o}c and as the refrigerator run the evaporator temp. is decrease and after some time it achieve to constant temp. During the starting of 15 minute evaporator temp. drop is high for all refrigerant and among the refrigerants R290 has high temp. drop and R 134a has low temp. drop. As shown in the fig R132a and R152A has achieved highest evaporating temp. after 150 min. and R 600 and R600a has a low evaporating temp.

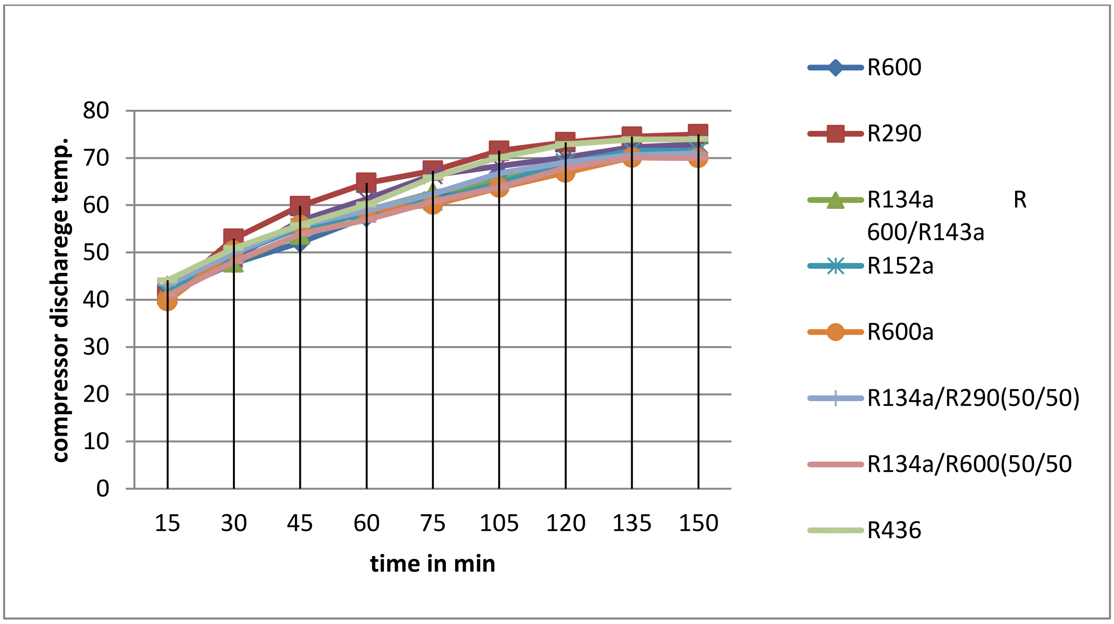

Fig 8: Time VS discharge temp.

As shown in the fig 5.2 the discharge temp. as the staring of refrigerator is low and than increase as the refrigerator and as the time pass the increase rate in discharge temp. is low and after some time it achieve constant temperature. So amoung the Refrigerant R290 has a highest discharge temp. while R 600 has a lowest discharge temp.

As shown in fig 5.3 the cop at staring of refrigerator is high and R 290 and R152a 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 fig is the clear that the COP of R 152a has a high value than another refrigerant and COP of R 290 and R 436a is also near to the COP of R 134a. And the refrigerant R 600 has low COP compare with another refrigerant blend of R 134/R 600an has low COP. Bt from fig. its also say that the R 152 and R 290 give the better performance than another alternate refrigerant. So its possible that the R 152a and R 290 has a better alternate refrigerant.

As Shown in fig 5.4 COP decrease as the evaporator temp. is decreasing and R 152a has a high COP at low evaporating temp. and the blend of R 600/134 and R 600 has low COP at low evaporating temp.

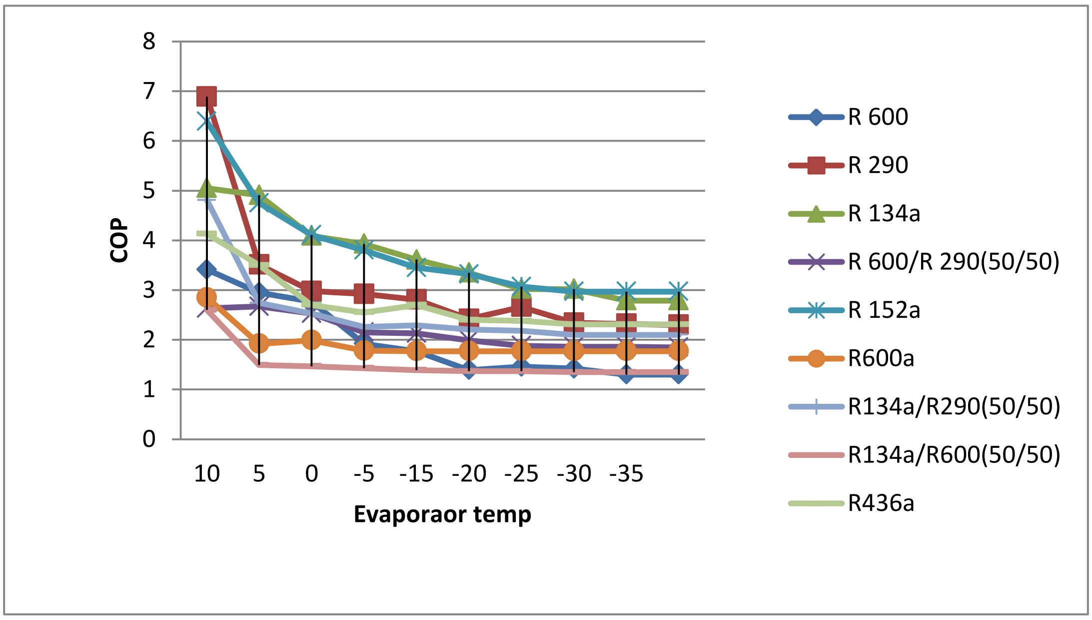

Fig 9: Evaporator temp vs cop

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As shown in the fig at staring of the time the refrigerant is high and than it is start deceasing as the time pass away and one time refrigerant effect is become constant it is due to the setting temp. difference in the cabinet . Now from fig is clear that the refrigerant effect of R 290 has high value than any another refrigerant . But at a same time the refrigerant effect is low for R 134a refrigerant. And from the fig it is also clear that the after some time refrigerant effect has a constant value.

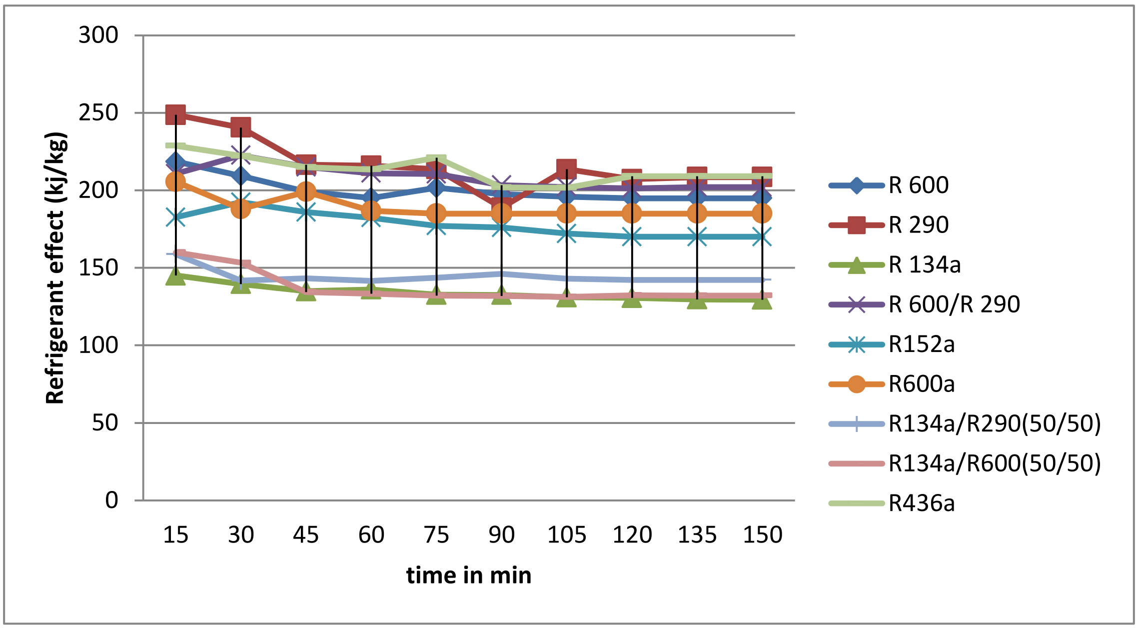

Fig 10: Refrigeraant effect vs time in min

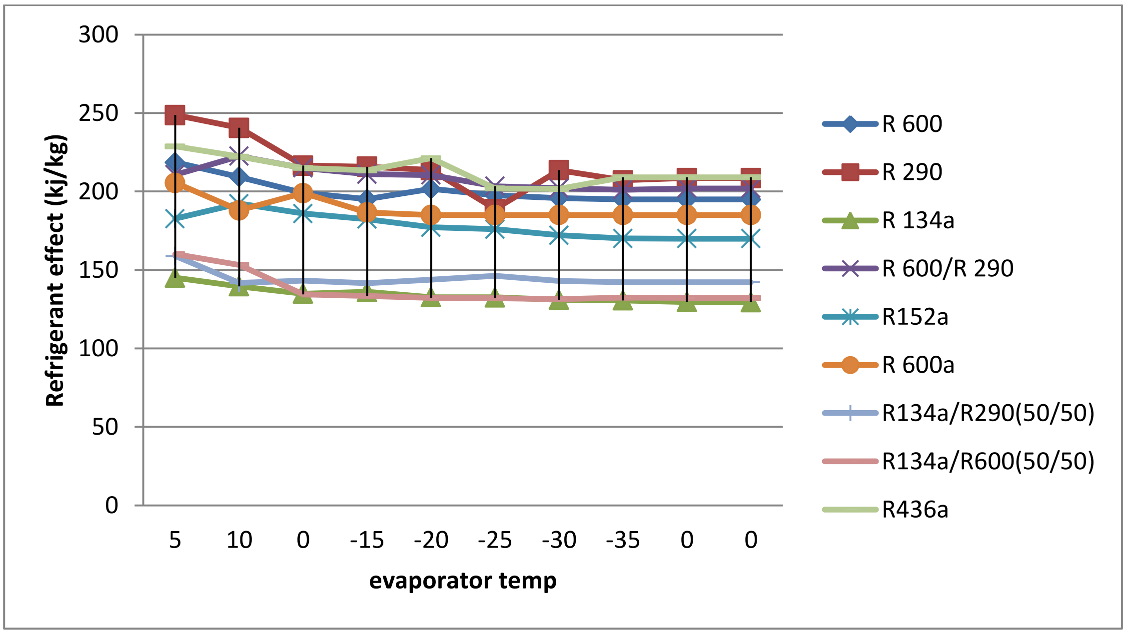

Fig 11: Refrigerant effect VS Evaporator Temp

Now from above fig it also clear that the with increasing the evaporator temp. the net refrigerant effect also decrease and achieve the constant value. Refrigerant R 152a and R 134a around the -35°c evaporating temp. low refrigerant effect and also achieve the constant value. While as a same temp. refrigerant R 290 and R 436a high refrigerant effect among the refrigerant

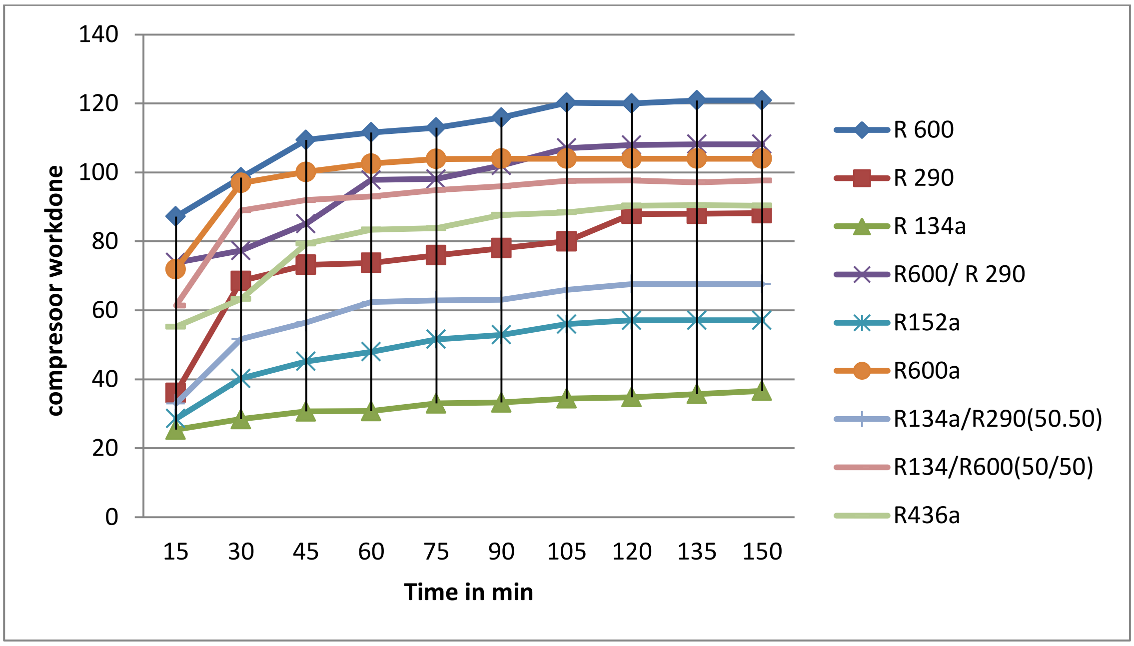

Fig 12: Compressor work done vs time

As shown in fig at the staring 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 fig it I clear that the compressor work done is low for R 134a and R 152a than another refrigerants . while the work done by the R 290 and R 436a Refrigerant is quite high than R 134a .Now compressor work for refrigerant R 600 is high and also work done for refrigerant R 600a is high than another refrigerant

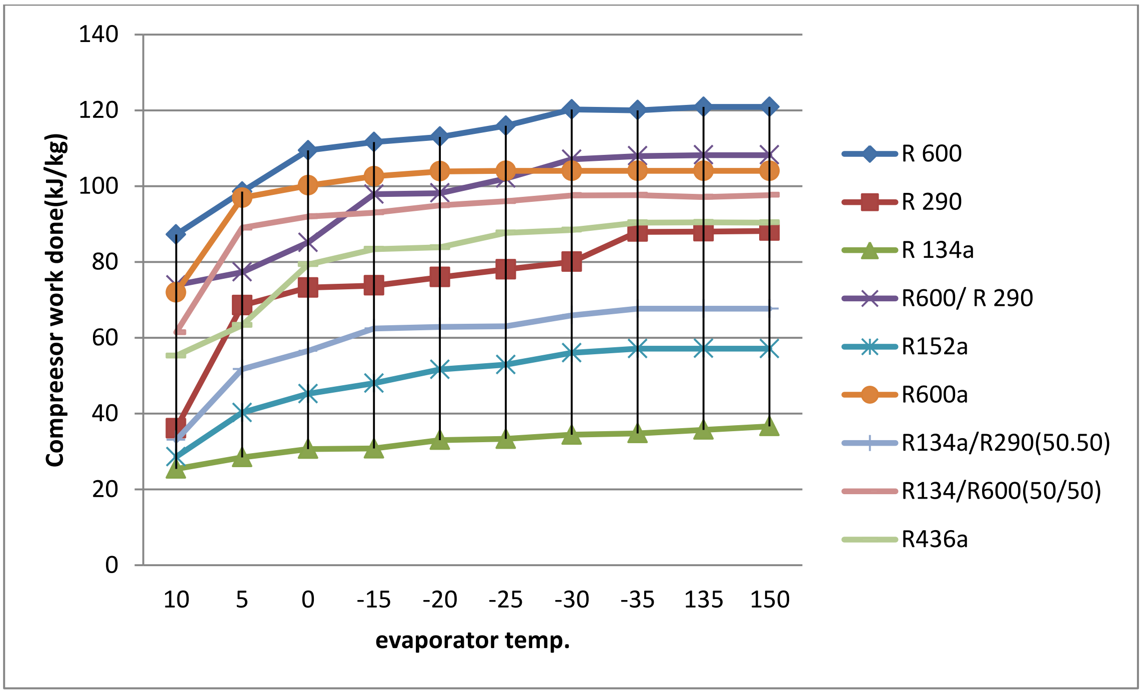

Fig 13: Compressor work done VS evaporator temp

As shown in fig it is clear that the Compressor work increasing as the evaporation temp increase. For R 134a at -35^{o}the compressor work is low than another refrigerant bt work done by the R 152a is near the work done of R 134a. And as the same evaporator temp. work done for R 600 and R 600a is high than another refrigerant.

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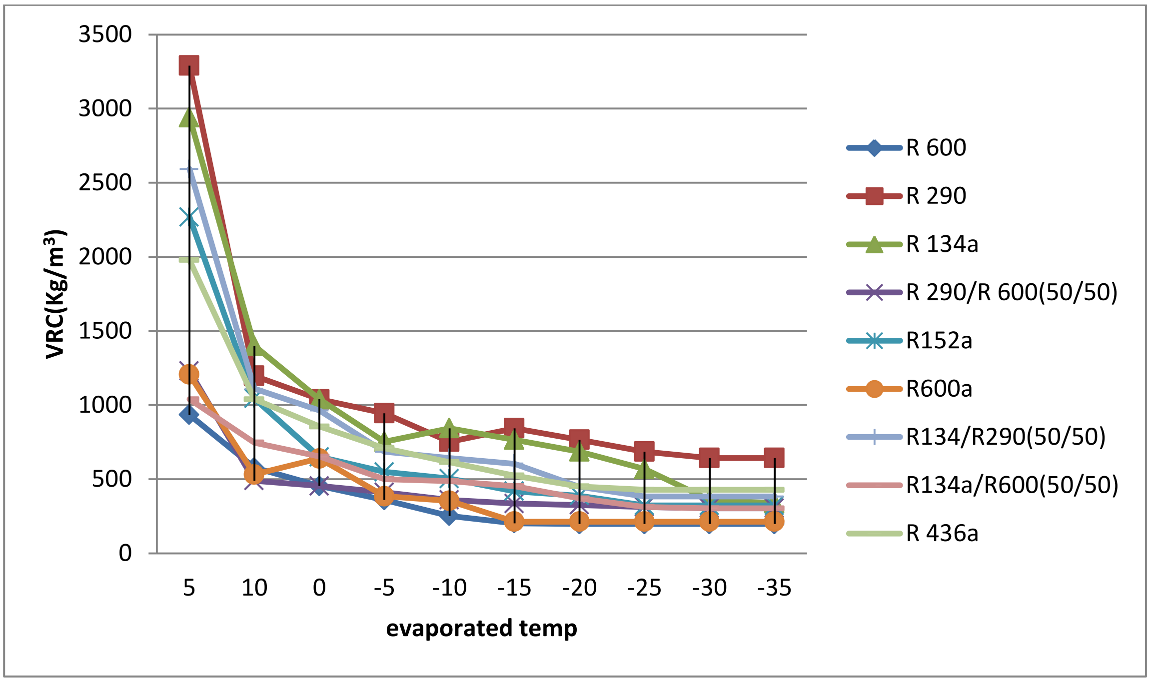

Fig 14: VRC VS evaporated temp

Now fig 5.10 its shows the variation of volumetric refrigerant capacity to the evaporator temp. from fig.it is clear that the VRC decrease as the evaporated temp. decrease so it is clear that the R 290 has high volumetric refrigerant capacity and R 134a and R 152a has a slightly low volumetric refrigerant capacity as compared to the R290 refrigerant. While as same temp. refrigerant R 600 and R 600a has low volumetric refrigerant capacity than another refrigerant.

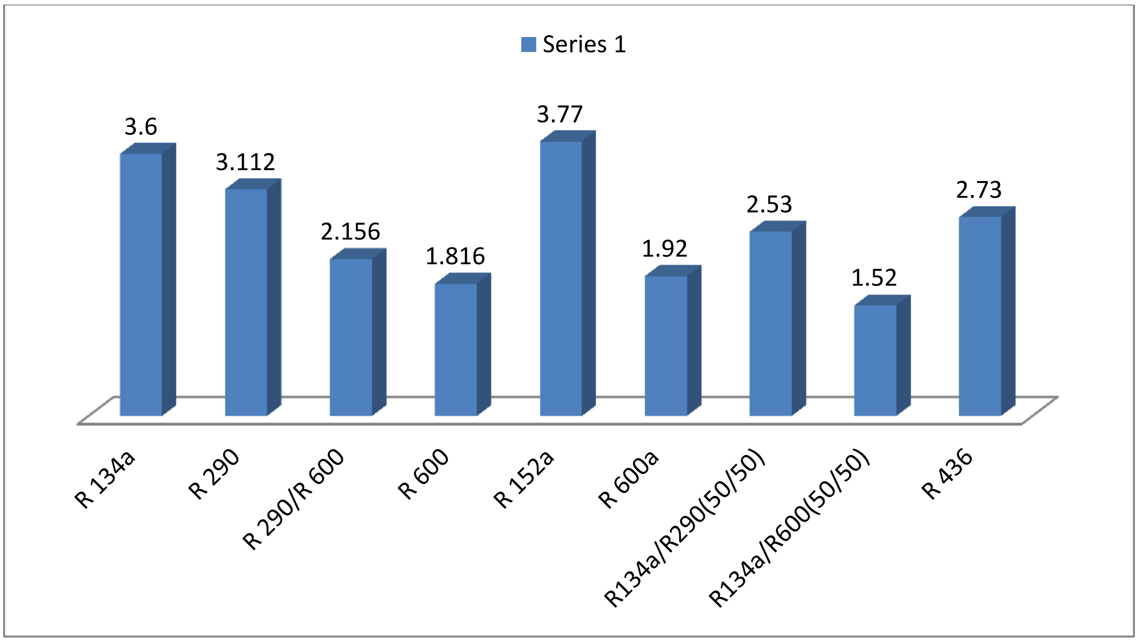

Fig 15: Avarage COP of Refrigerant

Fig. shows the avg. COP of all refrigerant. So from fig. it is clear that the avg. COP of the R 152a is high than another refrigerant and also high than R 134a and also avg. COP of R 290 is near the R 134a. while avg. COP of mixture of R 134 and R 600 is very low. Avg. COP of R 153a is 3.8 and R 134a 3.6 and lowest COP is 1.50 of mixture of R 134a and R 600

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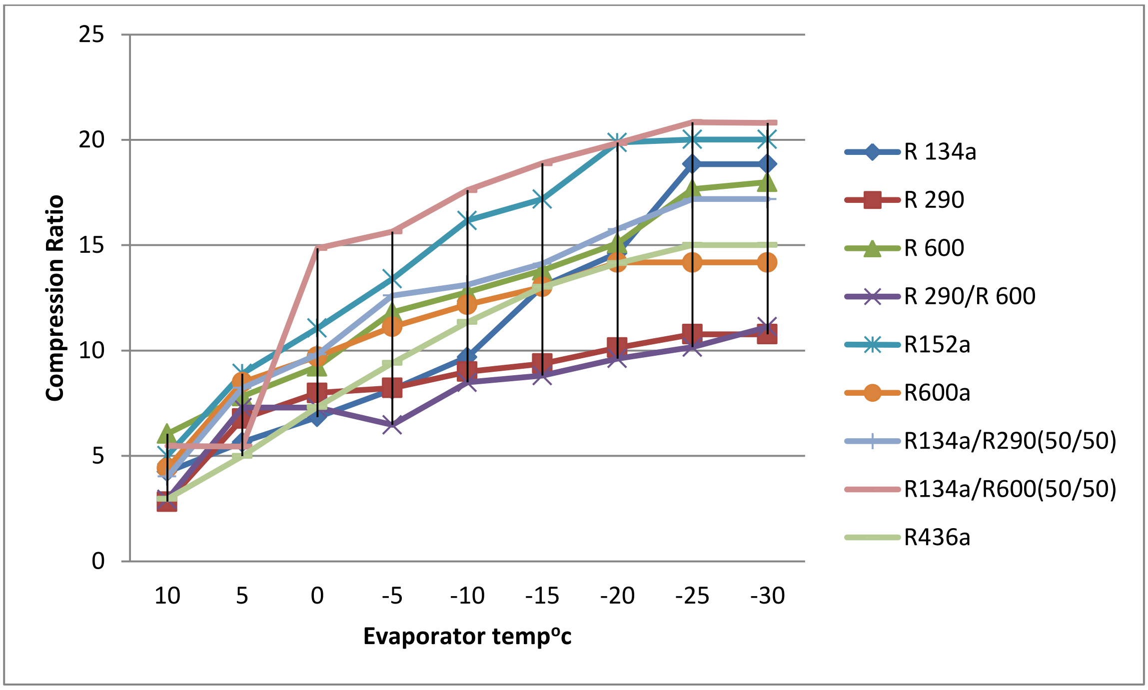

Fig 16: Compression ratio VS evaporater temp

As shown in the fig the compression ratio increase with decrease the evaporator temp. From fig, it is clear that the mixture of R 134a and R 600 and R 600 has high compression ratio and R 134a and R152a has same compression ratio while the Refrigerant R 290 and mixture of R 134a and R 290 has low compression ratio as same temp than any other refrigerant.

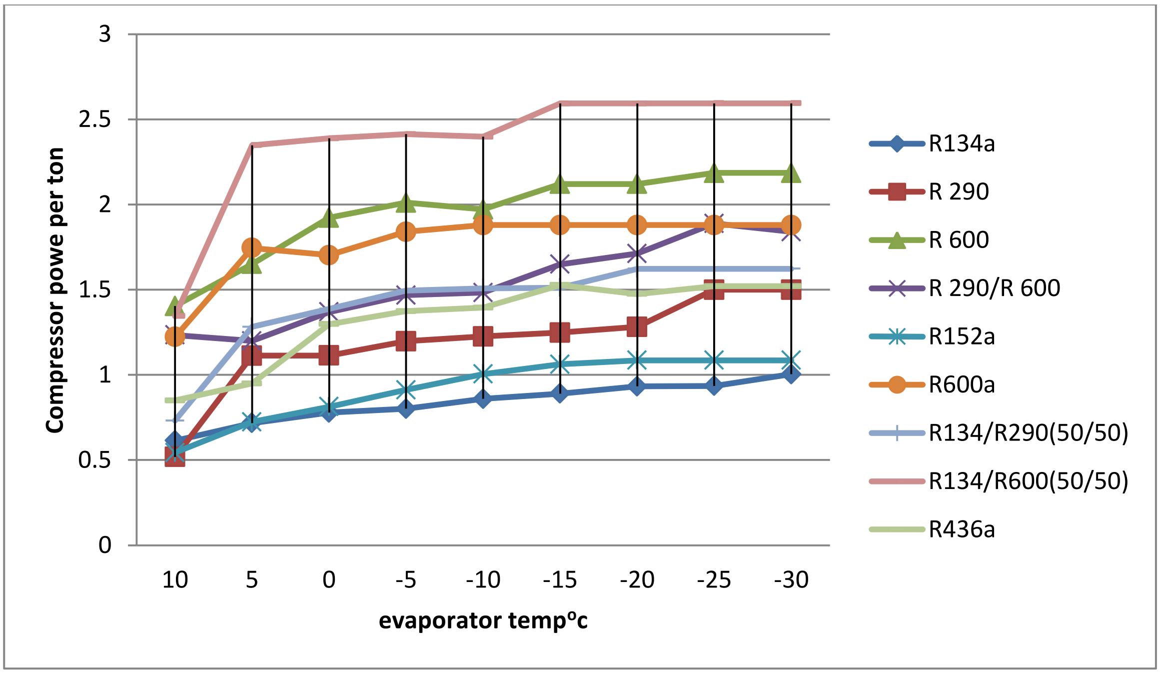

Fig 17: Compressor power per ton VS evaporator temp

As shown in the fig Compressor power per ton is increase as the temp. of evaporator increase. Compressor power per ton is high for the mixture of R134a and R600 and refrigerant R 600. While compressor power per ton is low for R 134a refrigerant and at -30°c temp. compressor power is same for refrigerant R 152a and R 134a

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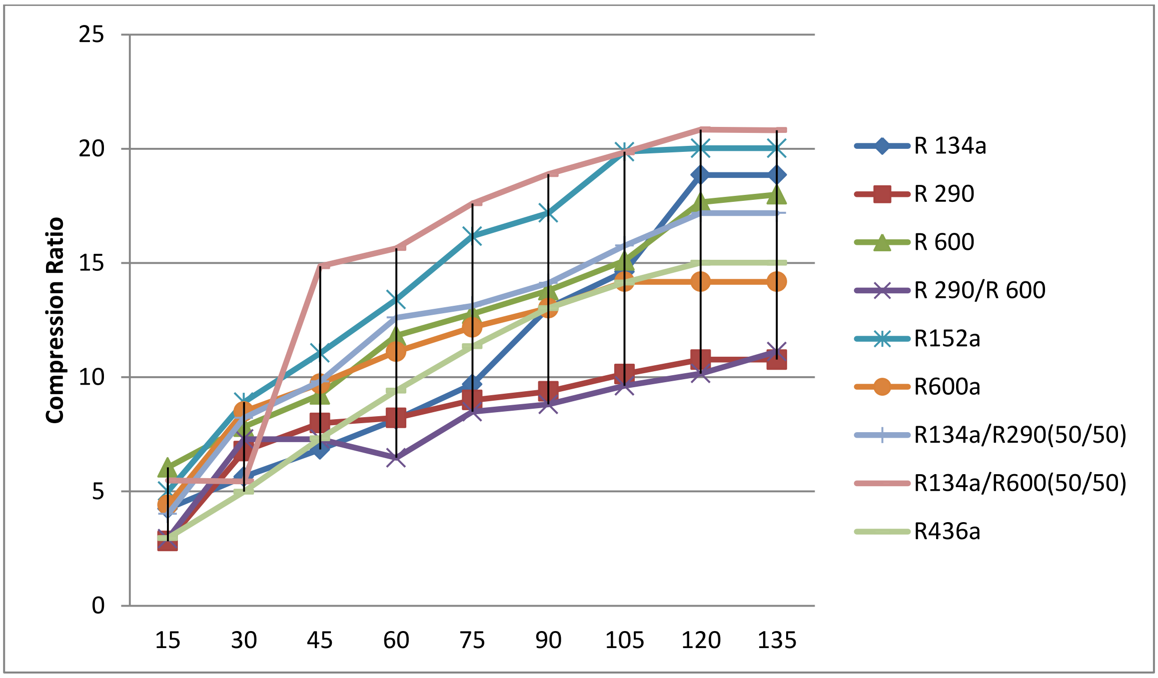

Fig 18: Compression ratio VS Time

As shown in the fig. compression ratio is increase as running time of refrigerator increase. At the starting of time compression ratio is low for all refrigerant but as the time pass away compression ratio increase due to increase in discharge temp. and after the running of 135 minitue compression ratio become constant. From the fig. it is clear that the compression ratio is low for R290 and R436a and high for R152a refrigerant

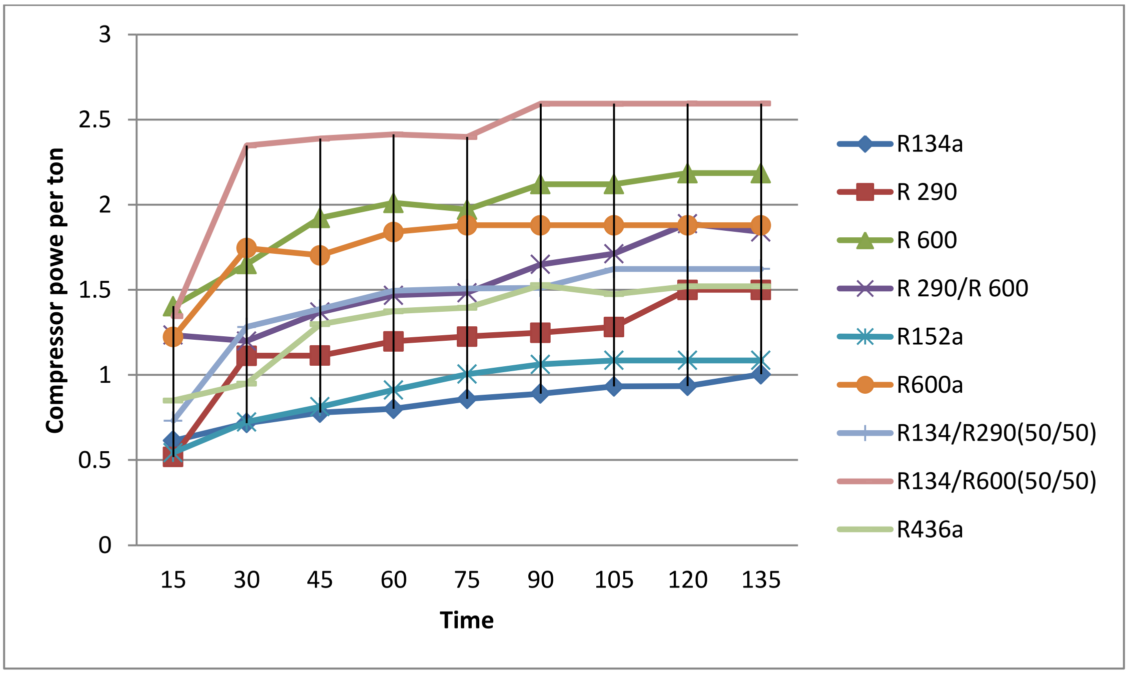

Fig 19: Compressor power per ton VS Time

As shown in Fig. Compression power per ton is increase as the time of refrigerator running is increase. And after some time it achieve constant value in this fig. after 135 minute running of refrigerator compressor power per ton become constant. For the R 134a and R152a has low compressor power in compare with another refrigerant.

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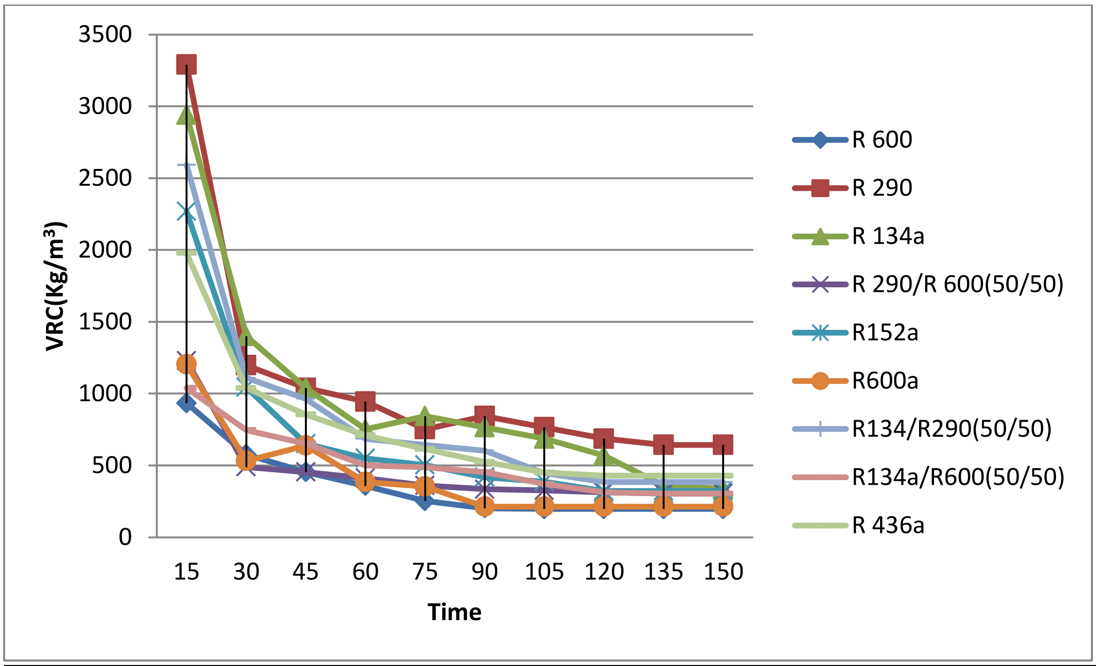

Fig 20: VRC VS Time

As shown in the fig. the volumetric cooling capacity is high for all refrigerants nt as the time pass away the volumetric cooling capacity is decrease and after some time it become constant. For R290 volumetric cooling capacity is high at the staring and after the 135 minute the volumetric cooling capacity of R290 is also high than another refrigerant I used.

4. CONCLUSION AND RESULTS

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:

1. Out all the refrigerants R290, R600a, R600 and R152a has the best desirable environment properties, it has zero Ozone Depletion Potential(ODP) and low global warming potential(GWP)
2. The COP of the R 152a Refrigerant is 17% is high than the R 134a and COP of R 290 is only 18% less than R 134a. During the evaporator temp. range of -25^{o}c to -30^{0}c R 152a has a high COP than another refrigerant while mixture of R 134a and R 600 and R 600 has low COP in compare with another refrigerant.
3. Discharge temp. of R 290 is highest in compare with another refrigerant and R 436a has slightly low discharge temp. than R290. R 134a and R 152a has same discharge temp. and R 600 and R 600 has low discharge temp. among the refrigerants.
4. Among the all refrigerants R290 has high refrigerant effect and is net refrigerant effect is 215.98KJ/Kg. And the refrigerant R 134a and R 152a has nearly same amount of refrigerant effect.
5. During the evaporator temp. rang of -20^{0}c to -30^{0}c R 152a has high compression ratio around the 20.22 while the R 134 has nearly same to the R 152a and its pressure ratio is 18.18 and Refrigerant R 600 and R 600a also compression ratio near the R 152a. While the R 290 and mixture of R 290 and R 600 has low compression ratio near the 11.11.
6. During the evaporator temp. rang of -20^{0}c to -30^{0}c the work done by the compressor is low for the R 134a around the 39.13 and the work done by the R 152a is slightly higher around the 17%.and for the R290 is 27 % higher than the R134a. And for the refrigerant R 600 and R 600a compressor work done is higher among the all refrigerant.
7. Now power consumption is low for R 152a and 18 % lower than the R 134a. power consumption for R 290 and R 436a is also high than R 134a and R 152a. Bt the refrigerant R 600a and R 600 and mixing of R134a and R 600 the power consumption is more high than the R 134a.

8. Volumetric cooling capacity For R 290 is high and is higher than R 134a is 12.2%. Volumetric cooling capacity is same for R 134a and R 152a. But Volumetric cooling capacity is much lower for the R 600 and R 600a around the 352.45Kg/m^3.
9. In this study I used the mixture of R134/R600(50/50), R290/R600(50/50) and R134a/R290(50/50).But this mixture has undesirable characterises such has a low COP, high power consumption, high compression ration and low volumetric cooling capacity. But from these three mixture the mixture of R134a/R290(50/50) is give better performance but this two refrigerant are not properly mix each other.
10. R436a refrigerant also give some better performance such as its COP is very low than the R 134a so in some cases it also use as the alternate of R 134a.
11. But R152a and R290 refrigerants has approximately same performance with the R134a. So R152a and R290 has good alternate of R134a refrigerant.

REFERENCES

[1] Performance comparison of vapour-compression refrigeration system using various alternative refrigerants A.S. Dalkilic, S. Wongwises

[2] The study and performance of a modified conventional refrigerator to serve as a PV powered one Socrates Kaplanis, Nikolaos Papanastasiou

[3] Performance of a domestic refrigerator under influence of varied expansion device capacity, refrigerant charge and ambient temperature Erik Bjork, Bjorn Palm

[4] Theoretical analysis of a vapour compression refrigeration system with R502, R404A and R507A Akhilesh Arora, S.C. Kaushik

[5] A review on exergy analysis of vapour compression refrigeration system J.U. Ahamed, R. Saidur, H.H. Masjuki

[6] Vapour Compression Refrigeration Systems, nptel IIT Kharagpur

[7] Khorshid E., Alshiraan B., Alsairafi A., Alzemi A., Allahddad A., 2011, "Performance investigation on new refrigerant mixture"pp15-20.

[8] Rasti M., Hatamipour M.S., Aghmiri S.F., Tavakoli M., 2012, "Enhancement of domestic refrigerator‟s energy efficiency index using a hydrocarbon mixture refrigerant," Measurement 45 pp:1807–1813.

[9] Sattar M. A., Saidur R., Masjuki H. H., 2007 "Performance investigation of domestic refrigerator using pure hydrocarbons and blends of hydrocarbons as refrigerants," World Academy of Science, Engineering and Technology 29 pp:223–228.

[10] Saidur R., Kazi S.N., Hossain M.S., Rahman M.M., Mohammed H.A.,2011, "A review on the performance of nano particles suspended with refrigerants and lubricating oils in refrigeration systems," Renewable and Sustainable Energy Reviews 15,pp: 310–323.

[11] Corberan J. M., Segurado J., Colbourne D., Gonzalvez J., 2008, "Review of standards for the use of hydrocarbon refrigerants in A/C, heat pump and refrigeration equipment," International Journal of Refrigeration 31, pp: 748–756.

[12] Cengel Y. A., Bole M. A., Thermodynamics, An Engineering Approach 7e. pp:610-611.

[13] Chen S., Judge J. F., Groll E. A., Radermacher R., 1994, "Theoretical Analysis of Hydrocarbon Refrigerant Mixtures as a Replacement for HCFC -22 for Residential Uses", International Refrigeration and Air Conditioning Conference, pp: 225-230.

[14] Kim M. H., Lim B. H., Chu E. S., 8 Oct 1998, "The Performance Analysis of a Hydrocarbon Refrigerant R-600a in a Household Refrigerator/Freezer", KSME International Journal, Vol. 12, No. 4, pp. 753~ 760.

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[15] Liu Z., Haider I., Liu B. Y., Radermacher R., 1994, “Test Results of Hydrocarbon Mixtures in Domestic Refrigerator/Freezers”, Center for Environmental Energy Engineering (CEEE) University of Maryland College Park, Maryland, USA, PP: 22-31.

[16] Maclaine-cross I. L., Leonardi E., June 1997, “Why Hydrocarbons Save Energy”, School of Mechanical and Manufacturing Engineering The University of New South Wales Sydney NSW, Australia 2052, Published in AIRAH Journal, Volume 51 No. 6, pp. 33–37.

[17] Baskaran A., Mathews P. K., September 2012, “A Performance Comparison of Vapour Compression Refrigeration System Using Eco Friendly Refrigerants of Low Global Warming Potential”, International Journal of Scientific and Research Publications, Volume 2, Issue 9, ISSN 2250-3153, pp: 1-8.

[18] Almeida I. M. G., Barbosa C. R. F., Fontes F. A. O., December 2010, “THERMODYNAMIC AND THERMOPHYSICAL ASSESSMENT OF HYDROCARBONS APPLICATION IN HOUSEHOULD REFRIGERATOR”, Engenharia Térmica (Thermal Engineering), Vol. 9, N o 01 e 02, pp. 19-27,