ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Experimental Analysis on VCR Using Hydrocarbon Mixture(R290/R600a)

D.Ram Murthy
PG Student (M.Tech Thermal Engineering),
Department of Mechanical Engineering,
Malla Reddy Engineering College,
Hyderabad, Telangana, India.

C.Chandra Sekhara
Assistant Professor,
Department of Mechanical Engineering,
Malla Reddy Engineering College,
Hyderabad, Telangana India.

ABSTRACT:
Due to Ecological problems like Ozone Depletion and Global Warming Potential certain refrigerant like R-12 has to be replaced. HCFC's (hydro chloroFluoro carbons) have been identified as prime foremost cause of ozone depletion. HFC's(hydro fluoro carbons) are substantially less damaging to ozone layer than HCFC's.Several refrigerants have emerged as substitute to R-12. The most widely used fluorocarbon refrigerants are R-134a is used as alternative for R-12. The energy performance of a domestic refrigerator has been assessed experimentally at various evaporator temperatures.In the present work experimental analysis of VCRS on Domestic Refrigerator using HFC134a, Azeotrope Blend 413a and HC Mixture (R290/R600a) as refrigerants.In this experimental set up all the three refrigerants i.e.R134a, R413a and HC Mixture (R290/R600a) are tested individually and performance characteristics like COP, Mass flow rate, Power consumption, Heat rejection in condenser are found and critical comparisons are drawn between these refrigerants and showed by graphical representation.

INTRODUCTION:
Thermodynamics can be defined as the science of energy. The name thermodynamics stems from the Greek words thermo(heat) and dynamics (power), which is most descriptive of the early efforts to convert heat into power. Today the same name is broadly interpreted to include all aspects of energy and energy transformations, including power generation, refrigeration, and relationships among the properties of matter. One of the most fundamental laws of nature is the conservation of energy principle. It simply states that during an interaction, energy can change from one form to another but the total amount of energy remains constant. That is, energy cannot be created or destroyed.

1.1.THERMODYNAMICS LAWS

Zeroth law
If two thermodynamic systems are each in thermal equilibrium with a third, then all three are in thermal equilibrium with each other.

First law
The first law of thermodynamics, also known as the conservation of energy principle, provides a sound basis for studying the relationships among the various forms of energy and energy interactions. Based on experimental observations, the first law of thermodynamics states that energy can be neither created nor destroyed during a process; it can only change forms. Therefore, every bit of energy should be accounted for during a process.
E in – E out =   E system

Second law

Kelvin Planck Statement
It is impossible for any device that operates on a cycle to receive heat from a single reservoir and produce a net amount of work. That is, a heat engine must exchange heat with a low-temperature sink as well.

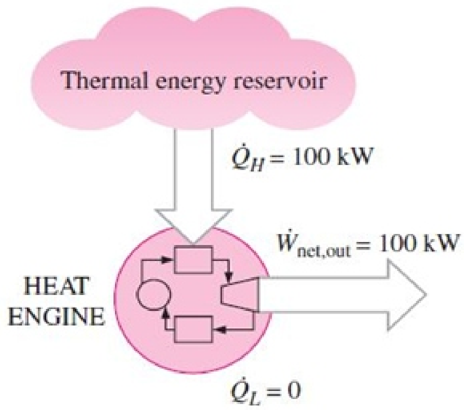


Figure 1.1: A heat engine that violates the Kelvin–Planck statement

Clausius statement

It is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a lower-temperature body to a higher-temperature body.

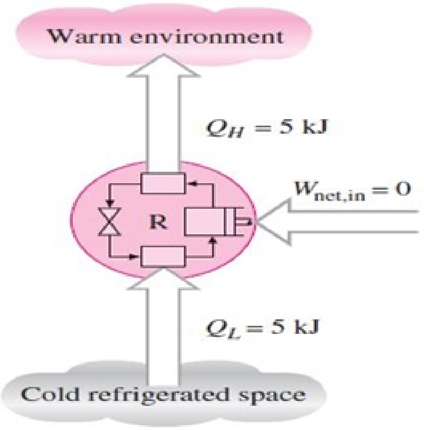


Figure 1.2: Refrigerator that violates clausius statement

Kelvin Planck Statement is related to heat engines while Clausius statement is related to refrigerators and heat pumps.

1.2. APPLICATIONS OF REFRIGERATION &Air Conditioning

The major applications of refrigeration can be grouped into following four major equally important areas.
1. Food processing, preservation and distribution
2. Chemical and process industries
3. Special Applications
4. Comfort air-conditioning

1.6.1. Application of refrigeration in Food processing, preservation and distribution Storage of Raw Fruits and Vegetables

It is well-known that some bacteria are responsible for degradation of food, and enzymatic processing cause ripening of the fruits and vegetables. The growth of bacteria and the rate of enzymatic processes are reduced at low temperature. This helps in reducing the spoilage and improving the shelf life of the food. In general the storage life of most of the food products depends upon water activity, which essentially depends upon the presence of water in liquid form in the food product and its temperature. Hence, it is possible to preserve various food products for much longer periods under frozen conditions.

Fish:

Icing of fish according to ASHRAE Handbook on Applications, started way back in 1938. In India, iced fish is still transported by rail and road, and retail stores store it for short periods by this method. Freezing of fish aboard the ship right after catch results in better quality than freezing it after the ship docks. In some ships, it is frozen along with seawater since it takes months before the ships return to dock. Long-term preservation of fish requires cleaning, processing and freezing.

Meat and poultry

These items also require refrigeration right after slaughter during processing, packaging. Short-term storage is done at 0^0C. Long-term storage requires freezing and storage at -25^0C.

Dairy Products

The important dairy products are milk, butter, buttermilk and ice cream. To maintain good quality, the milk is cooled in bulk milk coolers immediately after being taken from cow. Bulk milk cooler is a large refrigerated tank that cools it between 10 to 15^0C. Then it is transported to dairy farms, where it is pasteurized. Pasteurization involves heating it to 73^0C and holding it at this temperature for 20 seconds. Thereafter, it is cooled to 3 to 4^0C. The dairies have to have a very large cooling capacity, since a large quantity of milk has to be immediately cooled after arrival. During the lean period, the refrigeration plants of dairies are used to produce ice that is used during peak periods to provide cooling by melting. This reduces the required peak capacity of the refrigeration plant. Ice cream manufacture requires pasteurization, thorough mixing, emulsification and stabilization and subsequently cooling to 4 to 5^0C. Then it is cooled to temperature of about -5^0C in a freezer where it stiffens but still remains in liquid state. It is packaged and hardened at –30 to -25^0C until it becomes solid; and then it is stored at same temperature. Buttermilk, curd and cottage cheese are stored at 4 to10^0C for increase of shelf life. Use of refrigeration during manufacture of these items also increases their shelf life.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

There are many varieties of cheese available these days. Adding cheese starter like lactic acid and several substances to the milk makes all of these. The whey is separated and solid part is cured for a long time at about 10^0C to make good quality cheese.

Beverages:

Production of beer, wine and concentrated fruit juices require refrigeration. The taste of many drinks can be improved by serving them cold or by adding ice to them. This has been one of the favourite past time of aristocracy in all the countries. Natural or man-made ice for this purpose has been made available since a very long time. Fruit juice concentrates have been very popular because of low cost, good taste and nutritional qualities. Juices can be preserved for a longer period of time than the fruits. Also, fruit juice concentrates when frozen can be more easily shipped and transported by road. Orange and other citrus juices, apple juice, grape juice and pineapple juice are very popular. To preserve the taste and flavor of juice, the water is driven out of it by boiling it at low temperature under reduced pressure. The concentrate is frozen and transported at -20^0C. Brewing and wine making requires fermentation reaction at controlled temperature, for example lager-type of beer requires 8 to12^0C while wine requires 27-30^0C. Fermentation is an exothermic process; hence heat has to be rejected at controlled temperature.

1.6.2. Applications of refrigeration in chemical and process industries

Separation of gases

In petrochemical plant, temperatures as low as -150^0C with refrigeration capacities as high as 10,000 Tons of Refrigeration (TR) are used for separation of gases by fractional distillation. Some gases condense readily at lower temperatures from the mixtures of hydrocarbon. Propane is used as refrigerant in many of these plants.

Condensation of Gases

some gases that are produced synthetically, are condensed to liquid state by cooling, so that these can be easily stored and transported in liquid state. For example, in synthetic ammonia plant, ammonia is condensed at –10 to 10^0C before filling in the cylinders, storage and shipment. This low temperature requires refrigeration.

Dehumidification of Air

Low humidity air is required in many pharmaceutical industries. It is also required for air liquefaction plants. This is also required to prevent static electricity and prevents short circuits in places where high voltages are used. The air is cooled below its dew point temperature, so that some water vapour condenses out and the air gets dehumidified.

Solidification of Solute

One of the processes of separation of a substance or pollutant or impurity from liquid mixture is by its solidification at low temperature. Lubricating oil is dew axed in petroleum industry by cooling it below -25^0C. Wax solidifies at about -25^0C.

Storage as liquid at low pressure

Liquid occupies less space than gases. Most of the refrigerants are stored at high pressure. This pressure is usually their saturation pressure at atmospheric temperature. For some gases, saturation pressure at room temperature is very high hence these are stored at relatively low pressure and low temperature. For example natural gas is stored at 0.7 bar gauge pressure and -130^0C. Heat gain by the cylinder walls leads to boiling of some gas, which is compressed, cooled and expanded back to 0.7 bar gauge.

Cooling for preservation

Many compounds decompose at room temperature or these evaporate at a very fast rate. Certain drugs, explosives and natural rubber can be stored for long periods at lower temperatures.

Recovery of Solvents

In many chemical processes solvents are used, which usually evaporate after reaction. These can be recovered by condensation at low temperature by refrigeration system. Some of the examples are acetone in film manufacture and carbon tetrachloride in textile production.

1.6.3. Special applications of refrigeration

Cold Treatment of Metals

The dimensions of precision parts and gauge blocks can be stabilized by soaking the product at temperature around –90^{0}C.The hardness and wear resistance of carburized steel can be increased by this process. Keeping the cutting tool at –100^{0}C for 15 minutes can also increase the life of cutting tool. In deep drawing process the ductility of metal increases at low temperature. Mercury patterns frozen by refrigeration can be used for precision casting.

Medical:

Blood plasma and antibiotics are manufactured by freeze-drying process where water is made to sublime at low pressure and low temperature. This does not affect the tissues of blood. Centrifuges refrigerated at –10^{0}C, are used in the manufacture of drugs. Localized refrigeration by liquid nitrogen can be used as anaesthesia also.

Ice Skating Rinks

Due to the advent of artificial refrigeration, sports like ice hockey and skating do not have to depend upon freezing weather. These can be played in indoor stadium where water is frozen into ice on the floor. Refrigerant or brine carrying pipes are embedded below the floor, which cools and freezes the water to ice over the floor.

Construction:

Setting of concrete is an exothermic process. If the heat of setting is not removed the concrete will expand and produce cracks in the structure. Concrete may be cooled by cooling sand, gravel and water before mixing them or by passing chilled water through the pipes embedded in the concrete. Another application is to freeze the wet soil by refrigeration to facilitate its excavation.

Desalination of Water:

In some countries fresh water is scarce and seawater is desalinated to obtain fresh water. Solar energy is used in some cases for desalination. An alternative is to freeze the seawater. The ice thus formed will be relatively free of salt. The ice can be separated and thawed to obtain fresh water.

Ice Manufacture:

This was the classical application of refrigeration. Ice was manufactured in plants by dipping water containers in chilled brine and it used to take about 36 hours to freeze all the water in cans into ice. The ice thus formed was stored in ice warehouses. Now that small freezers and icemakers are available. Hotels and restaurants make their own ice, in a hygienic manner. Household refrigerators also have the facility to make ice in small quantities. The use of ice warehouses is dwindling because of this reason. Coastal areas still have ice plants where it is used for transport of iced fish.

1.6.4 Comfort Air-Conditioning:

Energy of food is converted into chemical energy for functioning of brain, lungs, heart and other organs and this energy is ultimately rejected to the surroundings. Also the internal organs require a temperature close to 35^{0}C for their efficient operation, and regulatory mechanisms of human body maintain this temperature by rejecting appropriate amount of heat. Human beings do not feel comfortable if some extra effort is required by the body to reject this energy. The air temperature, humidity and velocity at which human body does not have to take any extra action, is called comfort condition. Comfort condition is also sometimes called as neutral condition.

EXPERIMENTAL SETUP

A Domestic Refrigerator of capacity 165 litres is selected.

4.1 Instruments fitted to the Refrigerator
4.1.1 Pressure Gauges
Suction Pressure Gauge

This is joined in the suction line i.e., before the compressor by means of Gas Welding. It is used for measuring the pressure of vapour refrigerant before entering the compressor. Its range is from 0 to 17.5 bar.

IJMETMR
ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Fig 4.1: Suction Pressure gauge

Discharge Pressure Gauge

This is joined in the discharge line i.e., after the compressor by means of Gas Welding. It is used for measuring the pressure of the vapour refrigerant after leaving the compressor. Its range is from 0 to 35 bar.

Figure 4.2: Discharge Pressure gauge

4.1.2 Temperature Indicators :

Temperature Indicators are used for measuring the temperature of the refrigerant. In the present experimental work, and 4 Temperature indicators are used.

Figure 4.3: Thermocouples

4.2 Charging of refrigerant into Domestic Refrigerator

Figure 4.4: Refrigerator set up when Gas Charging of R134a

Figure 4.5: Refrigerator set up when Gas Charging of HC Mixture

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The following procedure is adopted for experimental set-up of the vapor compression refrigeration system

1.The domestic refrigerator is selected, working on vapor compression refrigeration system.
2.Pressure gauges are installed at entry and exit of the compressor.
3.Thermocouples are arranged each entry and exit of the all components.
4.R 134a refrigerant is charged in to the vapor compression refrigeration system by the following process:

The systematic line diagram for charging is shown in the fig.4.6 it is necessary to remove the air from the refrigeration unit before charging. First the valve V2 is closed and pressure gauge P2, vacuum gauge V are fitted as shown in the fig. the valve V5 is also closed and valves V1, V4, V6 and V3 are opened and the motor is started thus the air from the condenser receiver and evaporator is sucked through the valve V1 and it is discharged in to atmosphere through the valve V6 after compressing it in the compressor the vacuum gauge V indicates sufficiently low vacuum when most of the air is removed in the system. The vacuum reading should be at least 74 to 75 cm of Hg. If the vacuum is retained per above an hour it may be concluded that the system is free from the air. After removing the air the compressor is stopped and valves V1 and V6 are closed, the valves V5, V2 and V7 of the refrigerant cylinder are opened and then the compressor is started whenever the sufficient quantity of refrigerant is taken in to the system which will be noted in the pressure gauges. The compressor is stopped. The valves V7 and V5 are closed and valve V1 is opened the refrigerant cylinder is disconnected from the system the pressure gauge is used to note the pressure during the charging the system.

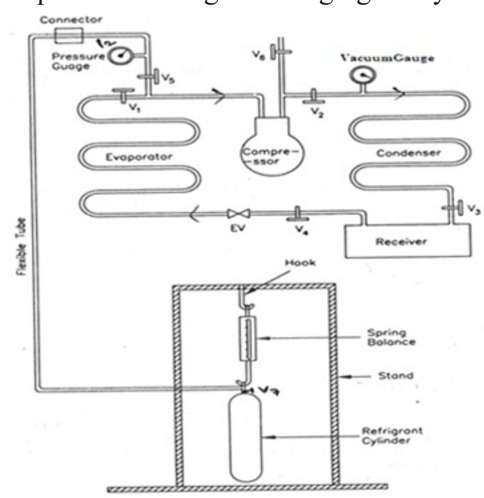


Figure 4.6: Charging of refrigeration system

5.Leakage tests are done by using soap solution, In order to further test the condenser and evaporator pressure and check purging daily for 12 hours and found that there is no leakages which required the absolutely the present investigation to carry out further experiment.
6.Switch on the refrigerator and observation is required for 3 hour and take the pressure and temperature readings at each section.
7.The performance of the existing system is investigated, with the help of temperature and pressure gauge readings.
8.The refrigerant is discharged out and condenser is located at the inlet of the capillary tube.
9.Temperature and pressure gauge readings are taken and the performance is investigated.
10.The readings are tabulated for calculating COP without placing shell and tube heat exchanger after the condenser.

Similarly other two refrigerants (R413a and HC Mixture(R290/R600a)) also charged as above procedure. And next observations are noted down such as suction and discharge pressures, temperatures at compressor inlet & outlet, condenser outlet and evaporator outlet. Calculations are done in next chapter.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

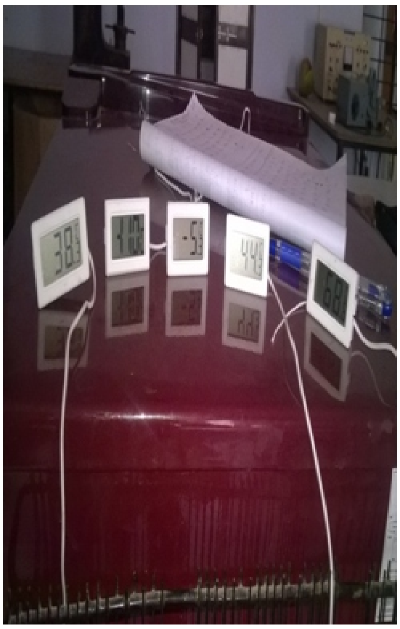
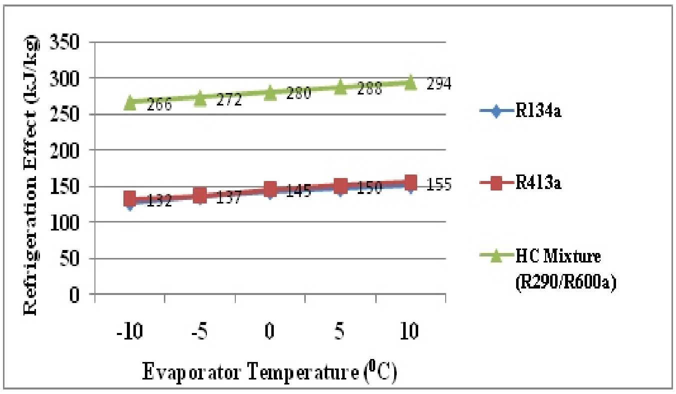


Figure 4.7 Refrigerator when experimental working

RESULTS AND DISCUSSIONS

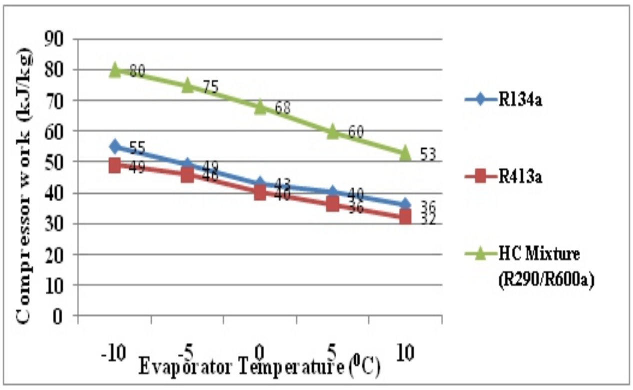
6.2.CRITICAL COMPARISIONS OF ALL THE THREE REFRIGERANTS

6.2.1.Refrigeration Effect v/s Evaporator Temperature



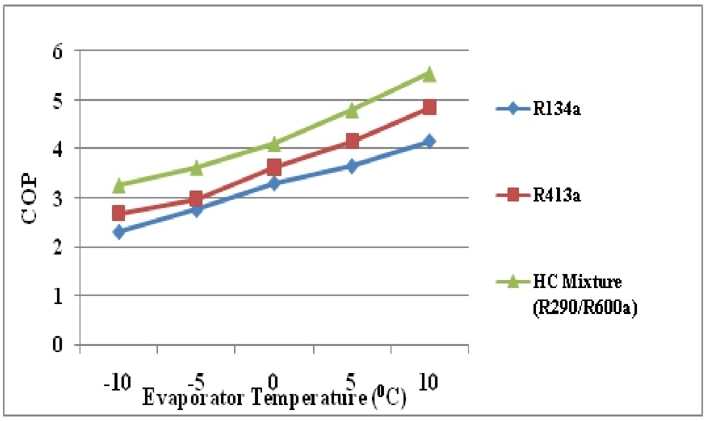
The graph 6.2.1 shows that the variation of Refrigeration Effect by varying evaporator temperature. As the evaporator temperature increased, Refrigeration effect also increased for three refrigerants at the same operating conditions. It is seen that at optimum temperature of -10^0 C, Refrigeration Effect of HC Mixture (R290/R600a) is 136 kJ/kg higher than the refrigerants R413a and R134a.

6.2.2. Compressor Work v/s Evaporator Temperature



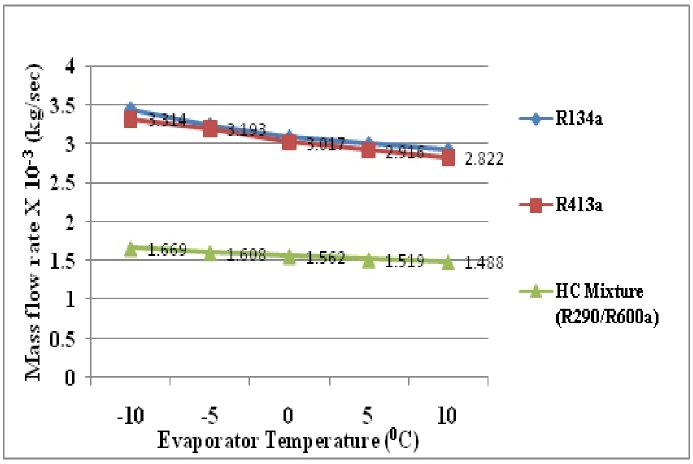
The graph 6.2.2 shows that the variation of Compressor work by varying evaporator temperature. As the evaporator temperature increased, Compressor work is decreased for three refrigerants at the same operating conditions. It is seen that at optimum temperature of -10^0 C, decrease in Compressor work for HC Mixture (R290/R600a) is 26kJ/kg higher than the refrigerants R413a and R143a.

6.2.3 Coefficient of performance v/s Evaporator Temperature



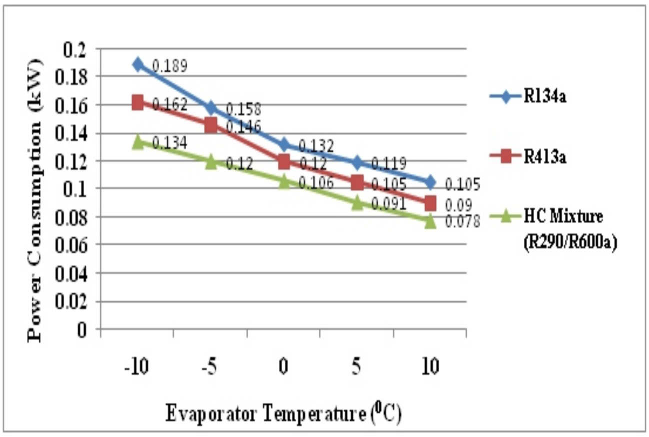
The graph 6.2.3 shows that the variation of Coefficient of performance by varying evaporator temperature. As the evaporator temperature increased, COP is also increased for three refrigerants at the same operating conditions.

6.2.4 Mass flow rate v/s Evaporator Temperature



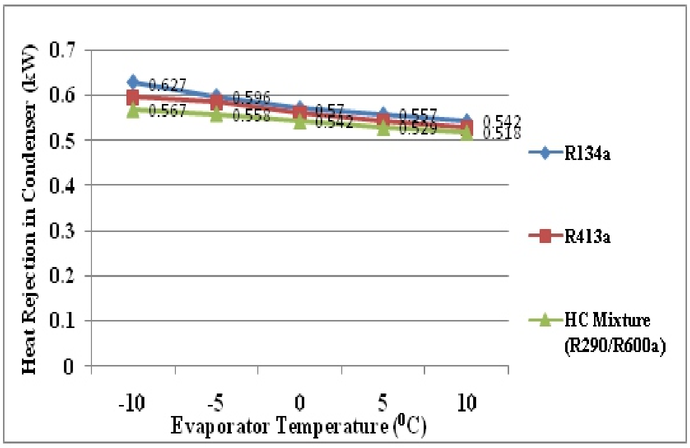
The graph 6.2.4 shows that the variation of Mass flow rate by varying evaporator temperature. As the evaporator temperature increased, Mass flow rate is decreased for three refrigerants at the same operating conditions. It is seen that at optimum temperature of -10⁰ C. Mass flow rate of HC Mixture (R290/R600a) is 0.9 x 10-3 kg/seclower than the refrigerants R413a and R134a.

6.2.5 Power Consumption v/s Evaporator Temperature



The graph 6.2.5 shows that the variation of Power consumption by varying evaporator temperature. As the evaporator temperature increased, Power consumption is decreased for three refrigerants at the same operating conditions. It is seen that at optimum temperature of -10⁰ C, Power Consumption for HC Mixture (R290/R600a) is0.042 kW lower than the refrigerants R413a and R134a.

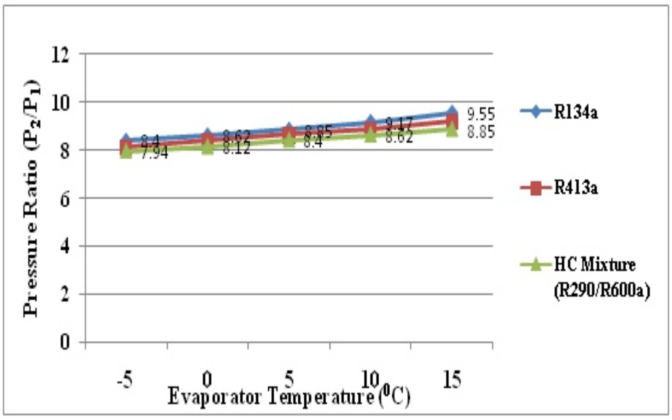
6.2.6 Heat rejection in condenser v/s Evaporator Temperature



The graph 6.2.6 shows that the variation of Heat rejection in condenser by varying evaporator temperature. As the evaporator temperature increased, Heat rejection in condenser is decreased for three refrigerants at the same operating conditions. It is seen that at optimum temperature of -10⁰ C, Heat rejection in condenser of HC Mixture (R290/R600a) is0.045 kj/sec lower than the refrigerants R413a and R134a.

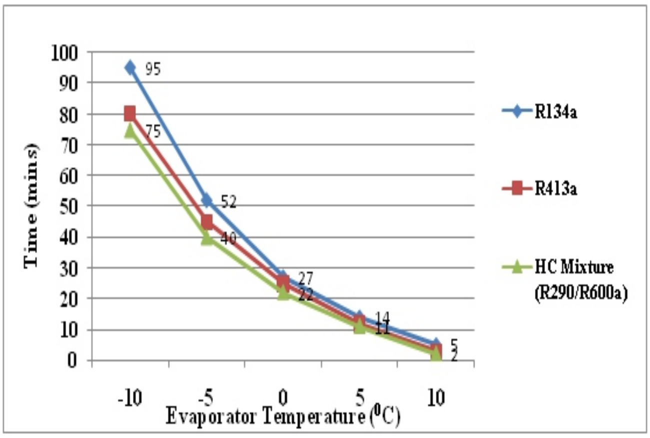
6.2.7 Pressure ratio v/s Evaporator Temperature

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal



The graph 6.2.7 shows that the variation of Pressure ratio by varying evaporator temperature. As the evaporator temperature increased, Pressure ratio is decreased for three refrigerants at the same operating conditions. It is seen that at optimum temperature of -10^0 C, Pressure ratios for HC Mixture (R290/R600a) is0.37lower than the refrigerants R413a and R134a.

6.2.8 Time (Pull down Period)v/s Evaporator Temperature



The graph 6.2.8 shows that the variation of time to reach required evaporator temperature (Pull down Period) by varying evaporator temperature. As the evaporator temperature increased, time is decreased for three refrigerants at the same operating conditions. It is seen that at optimum temperature of -10^0 C, time taking for reach required evaporator temperature for HC Mixture (R290/R600a) is 18 minutes lower than the refrigerants R413a and R134a.

CONCLUSION:

An experimental analysis is performed on Vapour Compression Refrigeration System with R134a, R413a, HC Mixture (R290/R600a) for their relative merits. In order to replace any refrigerant, first the detailed thermodynamic analysis is required. For this the performance parameters like Refrigeration effect, Compressor work, COP, Mass flow rate, Power consumption, heat removed rate in condenser were calculated for three refrigerants i.e. R134a, R413a, and HC Mixture (R290/R600a). Based on the results the following conclusion are drawn Over the entire range of operating conditions

1.The Refrigeration effect for HC Mixture (R290/R600a) is higher than the refrigerants R413a and R134a. Refrigeration Effect of HC Mixture (R290/R600a) is 136 kJ/kg higher than the refrigerants R413a and R134a.
2.Decreasing in Compressor work for HC Mixture (R290/R600a) is higher than the refrigerants R413a and R134a. Decrease in Compressor work for HC Mixture (R290/R600a) is 26 kJ/kg higher than the refrigerants R413a and R143a.
3.Coefficient of performance for HC Mixture (R290/R600a) is higher than the refrigerants R413a and R134a-COP of HC Mixture (R290/R600a) is 0.8 higher than the refrigerants R413a and R134a.
4.Mass flow rate for HC Mixture (R290/R600a) is lower than the refrigerants R413a and R134aMass flow rate of HC Mixture (R290/R600a) is 0.9 x 10-3 kg/sec lower than the refrigerants R413a and R134a.
5.Power consumption for HC Mixture (R290/R600a) is lower than the refrigerants R413a and R134a Power Consumption for HC Mixture (R290/R600a) is 0.042 kW lower than the refrigerants R413a and R134a.
6.Heat rejection rate in Condenser for HC Mixture (R290/R600a) is lower than the refrigerants R413a and R134a. Heat rejection in condenser of HC Mixture (R290/R600a) is 0.045 kW lower than the refrigerants R413a and R134a.
7.The operating pressure ratio for the HC mixture (R290/R600a) is lower than the refrigerants R413a and R134a.Pressure ratios for HC Mixture (R290/R600a) are 0.37lower than the refrigerants R413a and R134a.
8.Time taking for reach required evaporator temperature is lower for HC Mixture than Refrigerants R413a and R134a. Time taking for reach required evaporator temperature for HC Mixture (R290/R600a) is 18 minutes lower than the refrigerants R413a and R134a.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

From the above results it is also concluded that, all the performance parameters for R134a, R413a and HC Mixture (R290/R600a) behave similar and HC Mixture have high COP. Presently R134a is used as a transitional replacement for R12. But R134a has higher GWP. Hence permanent solution is necessary. HC Mixture (R290/R600a) with zero ODP and negligible GWP is a promising alternative.It is recommended that HC Mixture (R290/R600a) may be used as an alternative refrigerant for R134aapplications.

FUTURE SCOPE:

1) Further investigations can be conducted for different condenser and evaporator pressures and for wide range of evaporator temperatures.
2) Further experiments can be done with different combinations of Hydro carbons and performance of the refrigeration system can be analyzed.

REFERENCES

1.Mohd. AasimNazeer Ahmad, ChidanandMangrulkar, EhsanullahKhan, SyedMohiuddin, Experimental analysis of refrigerator by replacing conventional HFC refrigerants with hydrocarbons, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, PP 01-05. www.iosrjournals.org

2.Dr. AkashLangde, Junaid Ali, MohdShahid, MohdSultanet, Hydrocarbon Refrigeration System, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, PP 80-82. www.iosrjournals.org

3.Dr. AkashLangde, MohdMohsin, SayyadMaheboob, TanveerAhemadet, Performance Investigation of Domestic Refrigerator Using Pure
Hydrocarbons, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, PP 66-69. www.iosrjournals.org

4.SomchaiWongwiseset., Experiments to substitute R134a in a domestic refrigerator with hydrocarbon mixtures of R290, R600 and R600a.

5.M.A.Sattaret., Performance of the refrigerator using R600a, R600 and a ternary mixture of mixture of R290/R600a/R600 as refrigerants with theR134a.

6.M.Mohanrajet. Experimental investigation to find out a drop in replacement for R134a with the binary mixture of45.2%R290/54.8%R600a in a 200 liter single evaporator domestic refrigerator.

7.Ching-Song., Investigation on the substitute for R134a with the zeotropic mixture of 50%R290/50%R600a.

8.A Text book of Refrigeration and Air Conditioning by Domkundwar.

9.A Text book of Refrigeration and Air Conditioning by R.S. Khurmi and J.K.Gupta.

10.A Text book of Refrigeration and Air Conditioning by C.P Arora.

11.Thermodynamics an engineering approach by YunusA. Cengel , Michael A. Boles.

12.C.P. Arora, 'Refrigeration and Air Conditioning'. Tata McGraw Hill Publishing Company Ltd.,1981.