HYDROCARBON REFRIGERATION SYSTEM

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ABSTRACT

The investigation aims to apply the mixture of hydrocarbon refrigerants, R290 (propane) and R600a (isobutane) with each 50% component ratio, instead of refrigerant R134a for domestic refrigerators. The hydrocarbon refrigerants of R290 and R600a are friendly for environmental protection and have good refrigerating behavior in comparison with CFCs, HCFCs, or HFCs refrigerants. We have used 165 liter capacity domestic refrigerator for experiment, which generally works with 200g R134a refrigerant. During test the R134a refrigerant was replaced by hydrocarbon refrigerant, which was mixed by R290 and R600a. Main purpose of this refrigeration system is to reduce the Global Warming Potential (GWP) and maintaining Ozone Depletion Potential (ODP) as zero. Results also show that in comparison to the base refrigerator working with R134a, the ON time ratio and energy consumption per day were reduced by 12% and 5% respectively. The charge amount of refrigerant used in this system is reduced as compared to R134a hence increasing the COP of refrigerator.

Keywords: COP, Refrigeration effect, Evaporator Temperature, Global Warming Potential.

INTRODUCTION

Domestic refrigerators and freezers are identified as major energy consuming domestic appliances in every household. The most commonly used refrigerants in the late 1800s and in the early 1900s were natural refrigerants such as ammonia, carbon dioxide, sulphur dioxide and methyl chloride. All these refrigerants were found to be toxic or hazardous. In 1928, a safer class of alternative refrigerants became available with the invention of chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs). CFCs and HCFCs have many suitable properties such as stability, non–toxicity, non–flammable, good material compatibility and good thermodynamic properties, which led to their common wide spread use by both consumers and industries around the globe, especially as refrigerants in air–conditioning and refrigeration systems. Results from many researches show that ozone layer is being depleted due to the presence of chlorine in the stratosphere. The reason for the cause of this is that CFCs and HCFCs are large class of chlorine containing chemicals, which migrate to the stratosphere where they react with ozone. Later, chlorine atoms continue to convert more ozone to oxygen. The discovery of the depletion of the earth's ozone layer, which shields the earth's surface from UV radiation, has resulted in a series of international treaties demanding a gradual phase out of halogenated fluids. The CFCs have been banned in developed countries since 1996, and in 2030, producing and using of CFCs will be prohibited completely in the entire world. Also, the partially halogenated HCFCs are bound to be prohibited in the near future. Also according to Montreal and Kyoto protocols, R12 have been phased out by 2010 and the consumption of R134a must be reduced. The researchers are going on to find out some alternate refrigerants which does not harm to the environment and the protective ozone layer. Research has shown that hydrocarbons are good alternative to existing refrigerants.

LITERATURE REVIEW

Jwo et al. [1] used a blend of R–290 and R–600a instead of R–134a. The experiment was performed on a 440 liters domestic refrigerator. During test refrigerant R–134a was replaced with varied mass of hydrocarbon blends.

The results show that refrigerating effect was improved by using hydrocarbon blends. The refrigerator which was designed to work with 150 gm. of R–134a gave best result with 90 gm. of hydrocarbon refrigerant that implies a reduction of 40% in refrigerant charge. The design temperature was obtained quicker when the mixture of R–290 and R–600a was used that reduced the individual working time, hence the total working time per month was lesser than by using R–134a. On average, the new refrigerant mixture offers a better refrigerating behavior and reduces the energy consumption by 4.4%.

Rasti et al. [2] substituted R–134a with R–436a (mixture of R–290 and R–600a with a mass ratio of 56/44) in a 238 liter domestic refrigerator without any modification in the system. The compressor was charged with different amount of R–436a. The various results of the experiment showed that the refrigerant R–436a has better performance compared to R–134a considering various parameters. The ON time ratio was reduced by 13% when R–436a was used. The energy consumption per day was reduced by 5.3%. The refrigerant charge required in case of R–134a was 105g and the optimum amount of refrigerant for R–436a was 55g which implies a saving of 48% in refrigerant charge. The evaporator inlet temperature was reduced by 3.5oC. The energy efficiency index was raised from E to D. The results also showed that Total Equivalent Warming Impact (TEWI) of R–436a is 11.8% lesser than R–134a. Thus R– 436a appears to be a good replacement for R–134a.

Sattar et al. [3] used a domestic refrigerator to conduct trial which was designed to work with R–134a. The trial was conducted to check the possibility of using hydrocarbons as refrigerants. Pure butane, isobutane and mixture of butane, isobutane and propane were used as alternate refrigerants. The performance of the system was compared with R–134a. The compressor consumed 3% and 2% lesser energy when iso butane and butane were used at 28oC ambient condition. The amount of refrigerant charge with R–134a was 140 gm and it was reduced to 70 gm with the pure hydrocarbon and its blends which exhibits a saving of 50% in refrigerant charge. The trials were performed without any alteration in the system that shows the possibility of using hydrocarbons and their blends without any modification.

REFRIGERANT

Refrigeration is defined as any process of heat removal. More specifically, refrigeration is defined as the branch of science that deals with the process of reducing and maintaining the temperature of a space or material below the temperature of the surroundings.

R134a REFRIGERANT

The refrigerant R134a is a chemical compound tetrafluoroethane comprising of two atoms of carbon, two atoms of hydrogen, and four atoms of fluorine. Its chemical formula is CH_2FCF_3. The molecular weight of refrigerant R134a is 102.03 kg/kmol and is boiling point is -26.074^{0}C. R134a is nonflammable, non-explosive, and has toxicity within limits and good chemical stability. It has somewhat high affinity for the moisture.

HYDROCARBON REFRIGERANT

Hydrocarbon refrigerants are environmentally friendly, non-toxic, non-ozone-depleting replacement for chlorofluorocarbons (CFCs), hydro chlorofluoro carbons (HCFCs) and hydrofluoro carbons (HFCs). From a chemical point of view, a hydrocarbon is the simplest organic compound, consisting entirely of hydrogen and carbon. Hydrocarbons (HC) are naturally occurring substances. The majority can be found in crude oil, where decomposed organic matter provides an abundance of carbon and hydrogen.

The following hydrocarbons can be used as a refrigerant in cooling & heating applications:

R170 - Ethane - C2H6

R290 - Propane - C3H8

R600a - Isobutene (Isobutylene, 2-Methylpropene) - C4H8R600a - Isobutane (2-Methylpropane) - C4H10

However, the most commonly used HC refrigerants are propane (mainly in commercial and industrial freezers, air conditioning and heat pumps), and isobutane (in domestic refrigerators and freezers).

We are using the mixture of Propane & isobutane as refrigerant in the ratio of 50%

EXPERIMENTAL SETUP

1. Parts Required for Refrigerant Cycle
2. Hermetic Sealed Compressors
3. Condenser
4. Capillary Tube
5. Evaporator
6. Rotameter
7. Pressure Gauge
8. Digital Thermometer
9. Electric meter

WORKING PRINCIPLE

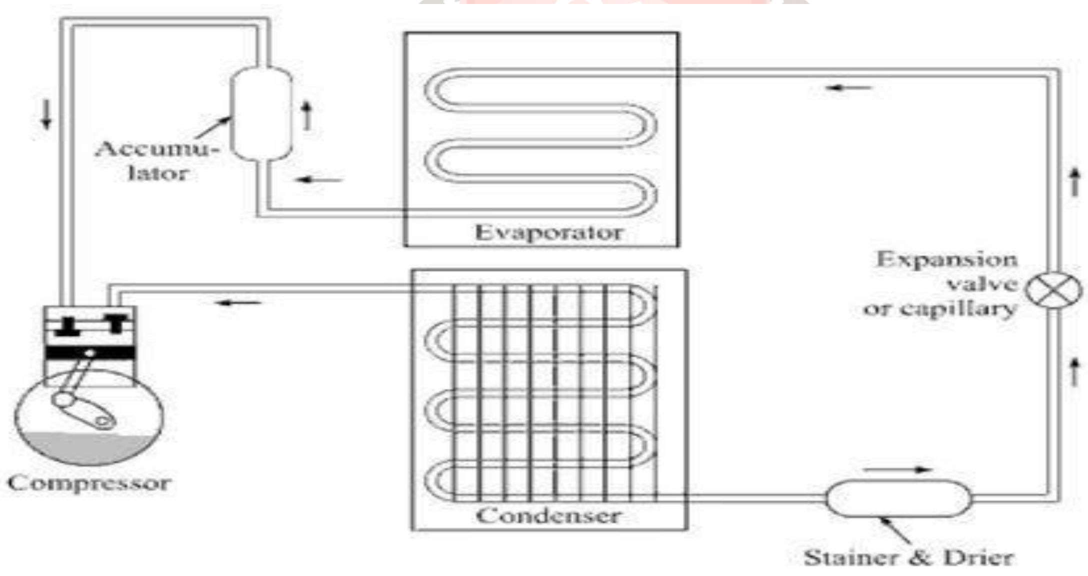


Fig. 3.1 Working Diagram of VCRS

Figure shows the schematic diagram of a simple vapour compression refrigeration system. The VCRS process can be explained in following manner:

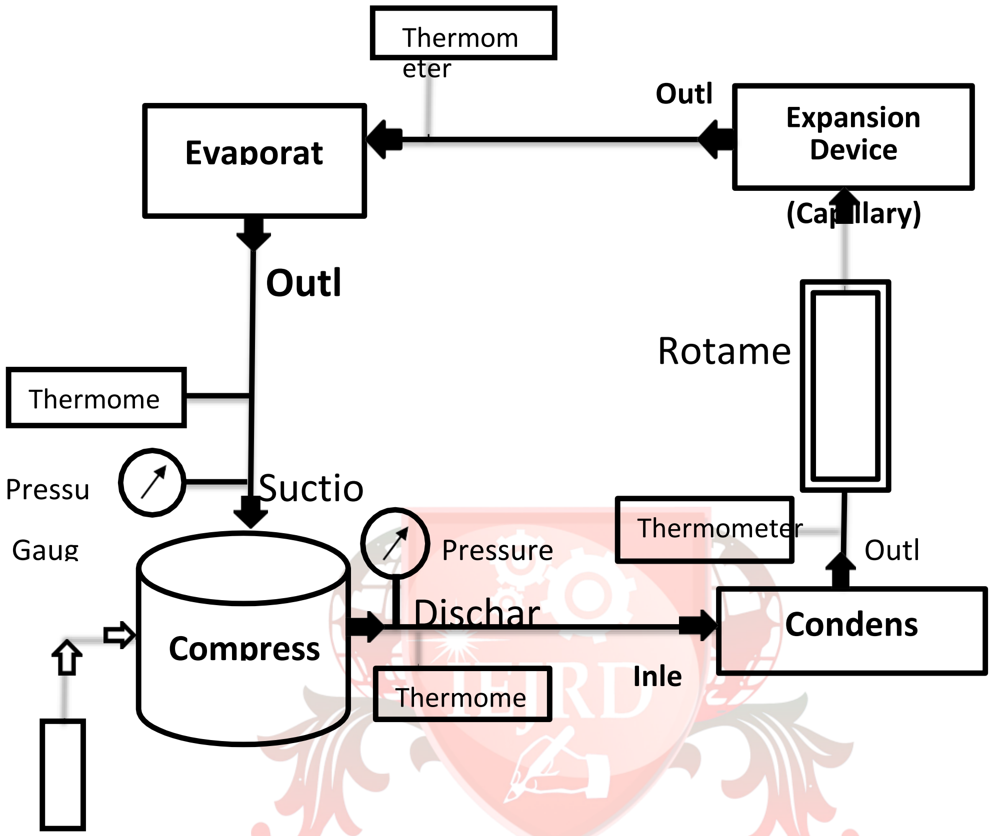
Compressor: The low pressure and temperature vapour refrigerant from evaporator is drawn into the compressor through the inlet or suction valve, where it is compressed to a high pressure and temperature. This high pressure and temperature vapour refrigerantis discharged into the condenser through the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

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

Capillary tube: The function of the capillary tube is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure andtemperature.

Evaporator: An evaporator consists of coils of pipe in which the liquid-vapour refrigerant at low pressure and temperature is evaporated and changed into vapour refrigerant at low pressure and temperature. In evaporating process, the liquid vapour refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which is to be cooled.

ACTUAL SYSTEM SETUP:



EXPERIMENTAL ANALYSIS:

SPECIFICATION OF COMPONENTS

Components	Refrigerator	R-134a Refrigerant	R-436a Refrigerant	Rota meter	Pressure gauge	Digital thermometer	Electric meter
Description	165 Liter	200 gram	200 gram	For measuring flow rate up to 50 LPH	At suction: Range 0-250 psi At discharge: Range 0-500 psi	Temp measuring device	Watt hour meter single phase

REFRIGERATION EFFECT & COP OF REFRIGERATION SYSTEM:

For 134a Refrigerant

Suction Pressure (psi)	8
Discharge Pressure (psi)	240
Evaporator OutletTemp.(^{0}C)	40.3
Compressor OutletTemp.(^{0}C)	80.2
Condenser OutletTemp.(^{0}C)	38.3

Evaporator Inlet Temp.(^{0}C)	-16.6
Cabin Temp. (^{0}C)	12.8
Flow Rate (LPH)	17
Power Consumption(kwh)	0.3

From chart of R134a the enthalpies are: $h_1 = 388\ KJ/Kg$

$$h_2 = 425\ \mathrm{KJ/Kg}$$

$$h_3 = h_4 = 255\ KJ/Kg$$

Mass flow rate,

$$m = \text{flow rate} \times \text{density}$$

$$m = \frac{17 \times 10^{-3} \times 1146.7}{3600} = 5.415 \times 10^{-3}\ \mathrm{kg/s}$$

Refrigeration effect,

$$RE = m(h_1 - h_4)$$

$$= 5.415 \times 10^{-3}(388 - 255) = 0.72\ KJ/sec$$

Work done

$$WD = m(h_2 - h_1)$$

$$= 5.415 \times 10^{-3}(425 - 388) = 0.2\ KJ/sec$$

$$COP = \frac{RE}{WD} = \frac{0.72}{0.2} = 3.6$$

For 436a Refrigerant

Suction Pressure(Psi)	5
Discharge Pressure(Psi)	235
Evaporator Outlet Temp.(^{0}c)	40.3
Compressor Outlet Temp.(^{0}c)	78
Condenser Outlet Temp.(^{0}c)	38
Evaporator Inlet Temp.(^{0}c)	-20.1
Cabin Temp. (^{0}c)	9.3
Flow Rate(Lph)	15
Power Consumption(Kwh)	0.25

From chart of R436a the enthalpies are:

$$h_1 = 545.33 KJ/Kg$$

$$h_2 = 612\ \mathrm{KJ/Kg}$$

$$h_3 = h_4 = 295.65\ KJ/Kg$$

Mass flow rate,

$$m = \text{flow rate} \times \text{density}$$

$$m = \frac{15 \times 10^{-3} \times 499.93}{3600} = 2.083 \times 10^{-3}\ \mathrm{kg/s}$$

Refrigeration effect,

$$RE = \mathrm{m}(\mathrm{h}_1 - \mathrm{h}_4)$$
$$= 2.073 \times 10^{-3}(545.33 - 295.65) = 0.52\ KJ/sec$$

Work done

$$WD = \mathrm{m}(\mathrm{h}_2 - \mathrm{h}_1)$$
$$= 2.083 \times 10^{-3}(612 - 545.33) = 0.139\ KJ/sec$$

$$COP = \frac{\mathrm{RE}}{\mathrm{WD}} = \frac{0.52}{0.139} = 3.74$$

CONCLUSIONS

This project invested an ozone friendly, energy efficient, user friendly, safe and cost-effective alternative refrigerant for R134a in domestic refrigeration systems. After the successful investigation on the performance of blend of HCs as refrigerants the following conclusions canbe drawn based on the results obtained:

- The Co-efficient of Performance (COP) for the blend of HCs is 3.74 which is comparable with the R134a having Co-efficient of Performance 3.6.
- The energy consumption by the blend of HCs is about similar to the energy consumption of refrigerator when R134a is used as refrigerant.
- Mixture of HCs offers lowest inlet refrigerant temperature of evaporator. So for the low temperature application blend of HCs is better than R134a.
- The domestic refrigerator was charged with 150g of R134a and 90g of blend of HCs. This is an indication of better performance of HCs as refrigerants.
- The experiment was performed on the domestic refrigerator purchased from the market, the components of the refrigerator was not changed or modified. This indicates the possibility of using HCs as an alternative of R134a in the existing refrigerator system.
- Global Warming Potential of mixture of isobutane and propane is 3 i.e. very less as compared to that of R134 which was 1430.
- Ozone Depletion Potential of this hydrocarbon refrigerant is zero.

Chemical and thermodynamics properties of hydrocarbon meet the requirement of a good refrigerant. Some standards allow the use of HCs as refrigerant if small amount of refrigerant is used. The final conclusion is that mixture of propane and isobutane can be used in the existingrefrigerator-freezer without modification of the components.

REFERENCES

[1] Ching Song Jwo, Chen–Ching Ting, Wei–Ru Wang, Efficiency analysis of home refrigerators by replacing hydrocarbon refrigerants, Measurement 42 (2009) 697–701.

[2] M. Rasti M.S. Hatamipour, S.F. Aghmiri, M. Tavakoli, Enhancement of domestic refrigerator’s energy efficiency index using a hydrocarbon mixture refrigerant, Measurement 45 (2012) 1807–1813.

[3] M.A. Sattar, R. Saidur, H.H. Masjuki, Performance investigation of domestic refrigerator using pure hydrocarbons and blends of hydrocarbons as refrigerants, World Academy of Science, Engg. And Technology 29 2007.