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"Performance Evaluation of Domestic Refrigerator Using Hc-12a Refrigerant as an Alternative Refrigerant to R12 And R134a"

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ABSTRACT: *This paper presents a study of different environment friendly refrigerants with zero ozone depletion potential (ODP) and negligible global warming potential (GWP), to replace R134a in domestic refrigerator. This work consists of using a hydrocarbon gas mixture which does not deplete ozone layer, is eco friendly, and can be used in the commonly used refrigerators without any significant change in the system. A refrigerator designed and developed to work with R134a was tested, and its performance using HC-12a was evaluated and compared with its performance when R134a was used. The condenser temperature and evaporator temperature, COP, refrigerating effect, condenser duty, work of compression and heat rejection of water were investigated. The energy consumption of the refrigerator during experiment with hydrocarbons and R-134a was measured. The results obtained showed that the alternative refrigerant investigated in experimental performance HC-12a have higher coefficient of performance and less energy consumption. The design temperature and pull-down time set by International Standard Organization (ISO) for small refrigerator were achieved earlier using refrigerant HC-12a than using R-134a. Due to a higher value of latent heat of HCs, the amount of refrigerant charge was also reduced as compared with HFC-134a. The COP and other result obtain in this experiment shows a positive indication of using mixed refrigerant as refrigerants in household refrigerator. The performance of HC-12a in the domestic refrigerator was constantly better than those of R134a throughout all the operating conditions, which shows that HC-12a can be used as replacement for R134a in domestic refrigerator. Refrigerant physical and chemical properties of different refrigerants are included in this paper. This paper also discuses on the C.O.P (coefficient of performance) and RE (Refrigeration Effect).*

KEY WORDS: *Experimental Domestic refrigerator, Hydrocarbon refrigerant, R134a, COP, Refrigerating effect, Energy consumption;*

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I. INTRODUCTION

The Montreal Protocol regulates the production and trade of ozone-depleting substances. Since the refrigerants used in air conditioning and refrigeration units contain chlorine, which causes the ozone depletion, the industry and research institutes are challenged to find suitable alternates. The Department of Energy's appliance energy standards, designed to contain the global warming effects, is another major challenge facing the refrigeration industry. The long-term reliability of the proposed alternate refrigerants is yet to be resolved.

Results from many researches show that ozone layer is being depleted due to the presence of chlorine in the stratosphere. The general consensus 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.

Many experimental and theoretical studies have been reported regarding the performance of various alternative refrigerants and their mixtures. A comprehensive survey of the existing literature on the performance of alternative refrigerants and their mixtures in refrigeration system has presented. An experimental study on domestic refrigerator with R–134a and replaced it by R–152a and R–32 which have zero ODP and low GWP. They were concluded that the system performed better than the other two refrigerants this shows that R–152a can be used to replace R–134a in domestic refrigerators. The plant working efficiency was first estimated with R–22 and then with three new HFC refrigerants, R–417a, R–422a and R–422d. The experimental results showed that R–22 has the least energy consumption among all the refrigerants under trial. Results also reveal that the three HFC refrigerants can replace R–22 without any change in lubricant or without any modification in the system and the accessories. The results also verified that despite these advantages, the performance of the new tested HFCs was not as efficient as with R–22.The hydrocarbons investigated are propane (R290), butane (R600) and isobutene (R600a). A refrigerator designed to work with R134a was used as an investigation unit to assess the prospect of using mixed refrigerants. Even the ozone depletion potentials of R134a relative to CFC-11 are very low; the global warming potentials are extremely high and also expensive. For this reason, the production and use of R134a will be terminated in the near future. Hydrocarbons are free from ozone depletion potential and have negligible global warming potential. In this work, an experimental work was investigated on the nano refrigerant were used in domestic refrigerator without any system reconstruction. The refrigerator performance was than investigated using energy consumption test and freeze capacity test. He was concluded TiO2–R600a nano refrigerant may be used in domestic refrigerator with better performance and lower energy consumption without any alteration of the system. 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 result shows that the new refrigerant mixture offers a better refrigerating behavior and reduces the energy consumption by 4.4%. This paper aims at development of one such eco friendly system for domestic refrigerators. The commonly used domestic refrigerators use the gas which either deplete the ozone layer or contribute in the global warming in the same as CO2 does. This work consists of using a hydrocarbon gas mixture known as mint gas which does not deplete ozone layer, is eco friendly, and can be used in the commonly used refrigerators without any significant change in the system. Efforts have been made to include various aspects to get the maximum knowledge about the refrigerant. This paper presents an experimental study of R404a and R134a, environment-friendly refrigerants with zero ozone depletion potential (ODP) and low global warming potential (GWP), to replace R134a in domestic refrigerator. A refrigerator designed and developed to work with R134a was tested, and its performance using R-404a was evaluated and compared with its performance when R134a was used.

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. Hydrocarbons, propane (R–290) and isobutane (R–600a) were among the first refrigerants, but due to their flammability and safety purposes, their use was abandoned and the direction of researches was shifted towards a safer and inert class of refrigerants. Thus the use of HCs as a refrigerant is not a new technology. Since 15 years, hydrocarbon and their blends are again being used at commercial scale.

A growing awareness of the environmental issues facing our planet has motivated many world leaders and governments to embrace hydrocarbon technology as a long-term solution to environmental concerns. The European Common has adopted a new Standard, EN 378, which provides guidelines for the use and installation of hydrocarbon refrigerants in over 14 European countries. In the past five years alone, more than 8 million refrigerators and freezers were manufactured in Germany and Denmark utilizing hydrocarbon technology. The Freon-dependent world was thrust into a dilemma in 1996 when production of the world's most commonly used refrigerant was banned in developed countries for its link to stratospheric ozone depletion. The immediate answer to the international refrigeration dilemma was to replace ozone-depleting chlorofluorocarbons (CFCs) with HFC-134a-a greenhouse gas.

R-134a TECHNOLOGY	HYDROCARBON TECHNOLOGY
Relatively lower efficiency than CFC 12	Slightly higher efficiency than CFC 12
Considerable changes in compressor manufacturing processes	No change in compressor manufacturing processes
Highly sensitive to moisture content	Negligible sensitivity to moisture content
High degree of cleanliness for the whole refrigeration system	Prevalent standards of cleanliness are acceptable
Higher potential of system malfunction due to accidental pollution	Negligible effect
Relatively higher noise-level	Low noise-level with isobutane as refrigerant
Non-flammable	Flammable
Higher cost of refrigerant and lubricant	Low cost
Essential to upgrade servicing practice	Existing service practice maybe followed with additional safety precautions
No safety measures are required	Safety measures are required

Table 1: Comparative study of HFC-134a and Hydrocarbon technologies from the point of view of manufacturing and servicing

It turns out that HFC-134a's potential for causing environmental damage is just the beginning of its inadequacy as a replacement for Freon. Field experience has shown it to be thermally inefficient, energy consumptive and corrosive to compressor parts. HFCs may be a source of acid rain. HFC degradation can include hydrofluoric acid and trifluoroacetate (TFA) which could threaten seasonal wetlands in urban areas. HFC production can leak toxic chemicals. The manufacture of HFCs releases vinyl chloride, ethylene dichloride (both carcinogens), other chlorinated organics, HFCs and HCFCs into the atmosphere. Liquid traces include heavy chlorinated residues likely to contain traces of dioxins as well as chromium in catalyst waste.

In addition, HFCs have been shown have toxic effects on refrigeration technicians whilst handling these refrigerants, leading to skin and stomach disorders and other effects such as headaches and dizziness. Within a fire situation, HFCs produce poisonous, toxic and corrosive substances when burned. A 1998 study conducted at Wright Patterson AFB in Ohio found that HFC-134a can be deathly toxic to humans who inhale it at levels at or above 4 parts per million. The issue of energy efficiency is of crucial importance in relation to the indirect global warming impact from CO2 emissions arising during energy production. Using a non-HFC substance or technology may have an important influence on energy usage.

	R-12	R-134a	HC-12a
Class	CFC (ChloroFluorocarbon)	HFC (HydroFluoroCarbon)	HC (HydroCarbon)
Chemical Name	Dichlorodifluoromethane CCl2F2	Tetrafluoroethane CH2FCF3	Isobutane & Propane CH(CH3)2-CH3 i-(C4H10) & CH2CH3CH2
Formula	R-12 (100)	R- 134a (100)	R-600a (40), R-290 (60)
Boiling Point @ 20°C	-29.7°C	-26.6°C	-29.8°C
Toxicity	Medium	Medium	Low
Flammability (auto- ignition temperature)	1100°C (non)	-800°C (non)	~ 460oC - ~ 470oC (yes)
Toxicity after ignition (by-products)	Very High	Extremely High	Extremely Low
Lubricant Flammability (auto-ignition temp.)	~ 200°C	~ 200°C	~ 200°C
Global Warming Potential (20 years / 100years)	8500/8500	3100/ 1300	~ 0/3
Ozone Depletion Potential I	Yes	No	No
Atmosphere Lifetime (Years)	~ 130	~ 16	<1
Cooling Performance @ 40°C	Good	Poor	Excellent
Energy Efficiency	Medium	Low	High
Power Consumption	Medium	High	Low
Average System Charge by Weight	~ 900 grams	~ 840 grams	<300 grams
Average System Charge by Volume	~ 0.90 Lt	~ 0.86 Lt	~ 0.75 Lt

Table 2: Properties of R-12, R-134a and HC-12a refrigerants with Comparison chart.

In some cases the effect can be beneficial. However, in other situations there is an energy penalty, which can actually lead to an increase in COZ emissions that outweigh the benefits of reduced HFC emissions. These effects are strongly application and design dependent and must be carefully taken into account when considering HFC emission reduction strategies. This is a topic intense discussion as there is no general rule because refrigerants and refrigeration technologies can behave differently in different systems under different conditions. However, numerous research work has illustrated that non-HFC technologies can provide more efficient refrigeration cycles than those using HFCs.

II. EXPERIMENTAL SETUP AND TEST PROCEDURE

This section provides a description of the facilities developed for conducting experimental work on a domestic refrigerator. The technique of charging and evacuation of the system is also discussed here. Experimental data collection was carried out in the research laboratory of our institution. The experimental setup of the test unit and apparatus is shown in the Figure.

2.1Experimental System

Figure 1: View of Experimental Refrigerator

Different experimental and theoretical comparison will performed to evaluate the performance of domestic refrigerator by using different refrigerants. In this experimental study of HC-12a is compared with the R-134a in a domestic refrigeration system. To perform the experiment 165L refrigerator is selected which was designed to work with R-134a. It is consists of an evaporator, air cooled condenser, expansion device and reciprocating compressor. The refrigerator was instrumented with two pressure gauges at inlet and outlet of the compressor. The temperature at six different points is taken by six temperature sensors are mounted to measure the compressor inlet temperature, compressor delivery temperature, evaporator inlet temperature, evaporator outlet temperature, the freezer temperature and cabinet temperature. An ammeter is mounted at the inlet of the compressor to measure the power supply and voltmeter is also used for voltage of supply.

Firstly cleaning is done with the help of nitrogen gas then evacuation is carried out with the help of vacuum pump and refrigerant is charged with the help of charging system. The refrigerant charge requirement with hydrocarbons is very small due to their higher latent heat of vaporization. As per the refrigerator manufactures recommendation quantity of charge requirement for HFC134a was 100 g. In the experiment, refrigerant charge is 10% higher due to the presence of instruments and connecting lines etc. To optimize the mixed refrigerant charge, the refrigerator is charged with 80g and the performance was studied. The experimental procedures were repeated and take the reading for different mixtures from the various modes.

2.2 Experimental Procedure

Heat flows naturally from a hot to a colder body. In refrigeration system the opposite must occur i.e. heat flows from a cold to a hotter body. This is achieved by using a substance called a refrigerant, which absorbs heat and hence boils or evaporates at a low pressure to form a gas. This gas is then compressed to a higher pressure, such that it transfers the heat it has gained to ambient air or water and turns back (condenses) into a liquid. In this way heat is absorbed, or removed, from a low temperature source and transferred to a higher temperature source. The refrigeration cycle can be broken down into the following stages

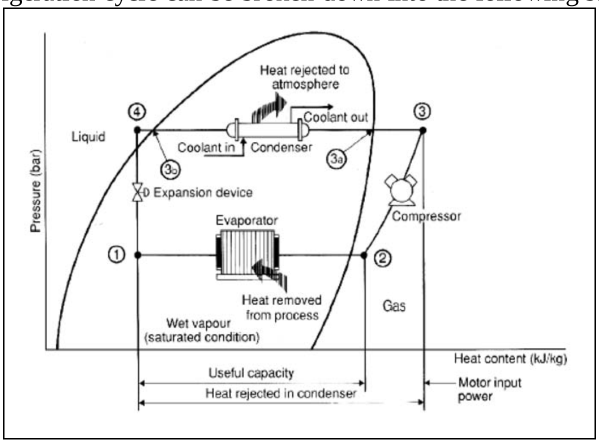

Figure 2: Schematic of a Basic Vapor Compression Refrigeration System

1 – 2: Low pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.
2 – 3: The superheated vapour enters the compressor where its pressure is raised. There will also be a big increase in temperature, because a proportion of the energy input into the compression process is transferred to the refrigerant.
3 – 4: The high pressure superheated gas passes from the compressor into the condenser. The initial part of the cooling process (3 - 3a) desuperheats the gas before it is then turned back into liquid (3a - 3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b - 4), so that the refrigerant liquid is sub-cooled as it enters the expansion device.
4 – 1: The high-pressure sub-cooled liquid passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator.

III. RESULTS AND DISCUSSIONS

3.1 Observations and calculations for R-134a as a refrigerant at no load condition

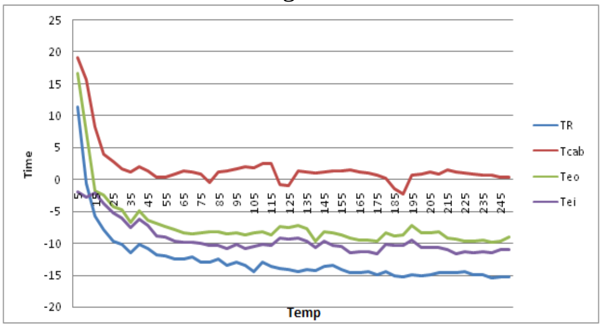

Figure 3: Time Vs TR, Tcab, Teo, Tei shows that at no load condition freezer temperature obtained is very low as compared to other temperature and cabinet temperature is not less than the other temperature.

At 60watt condition

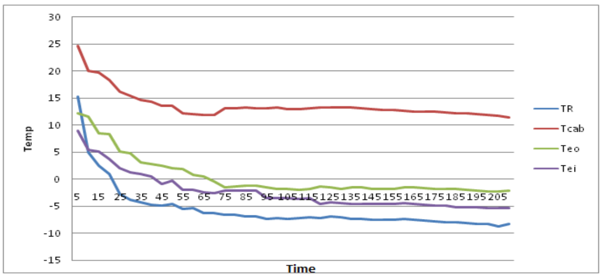

Figure 4: Time Vs T_R, Tcab, Teo, Tei shows that at 60w condition freezer temperature obtained is very low as compared to other temperature

At 120watt condition

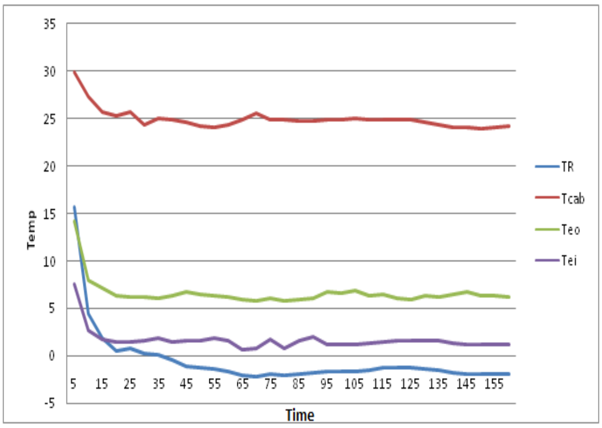

Figure 3: Time Vs T_R, Tcab, Teo, Tei shows that at 120watt condition freezer temperature obtained is low as compared to other temperature.

At 160watt condition

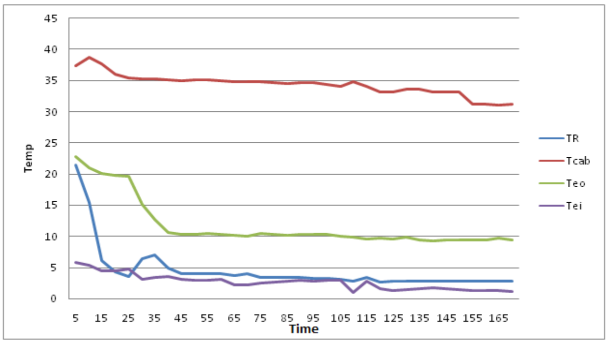

Figure 6: Time Vs T_R, Tcab, Teo, Tei shows that at 160watt condition Evaporator inlet temperature obtained is comparatively low as compared to other temperature and cabinet temperature is higher upto the 30^{o}C.

At 50lit water cabinet condition

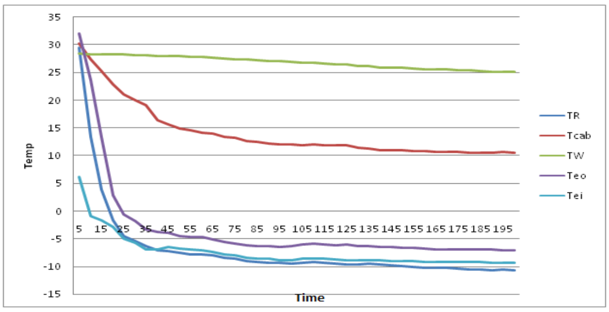

Figure 7: Time Vs T_R, Tcab, Teo, Tei and Tw shows that at 50lit water inside cabinet condition freezer temp. obtained is comparatively low as compared to other temperature.

3.2 Observations and calculations for HC-12a as a refrigerant

At no load condition

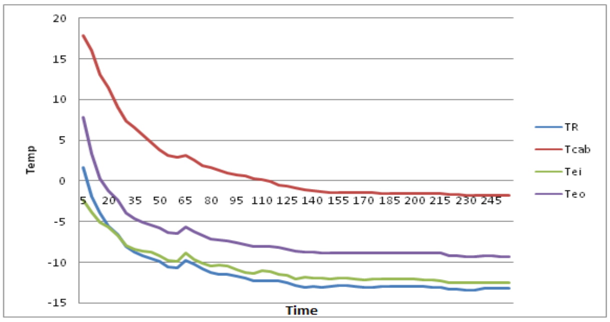

Figure 8: Time Vs TR, Tcab, Tei and Teo shows that freezer temperature is obtained very low as compared to other at no load condition.

At 60watt condition

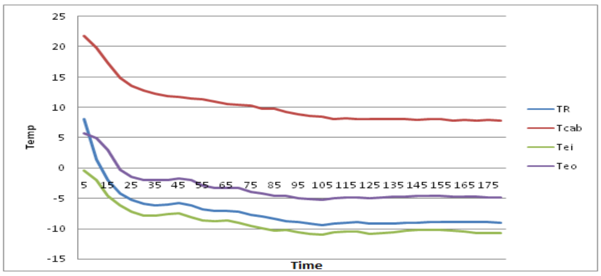

Figure 9: Time Vs TR, Tcab, Tei and Teo shows that cabinet temperature is obtained higher due to 60watt bulb cond. and evaporator inlet temperature is obtained very low as compared to with each other at 60watt condition.

At 120watt condition

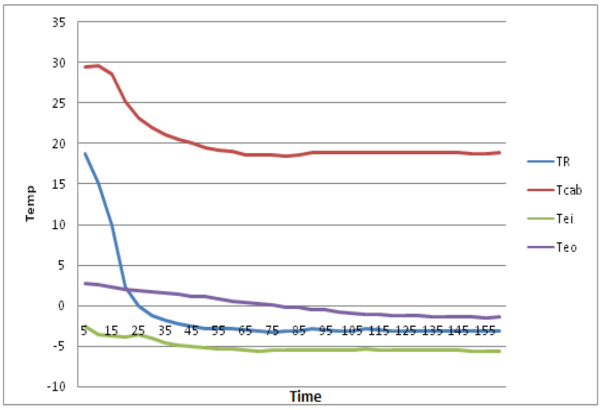

Figure 10: Time Vs TR, Tcab, Tei and Teo shows that cabinet temperature is obtained higher due to 120watt bulb condition as compared to other temperature.

At 160watt condition

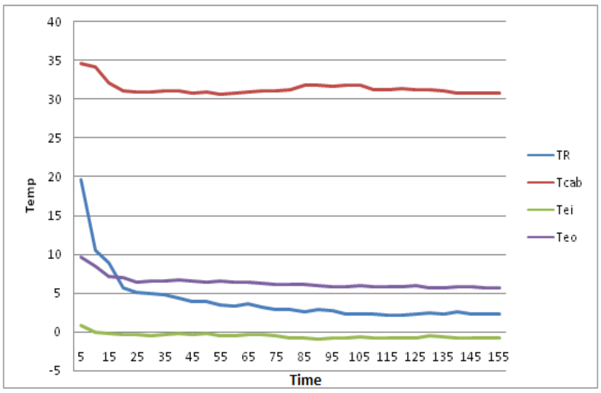

Figure 11: Time Vs TR, Tcab, Tei and Teo shows that cabinet temperature is obtained higher due to 160watt bulb condition as compared to other temperature.

At 50lit water cabinet condition

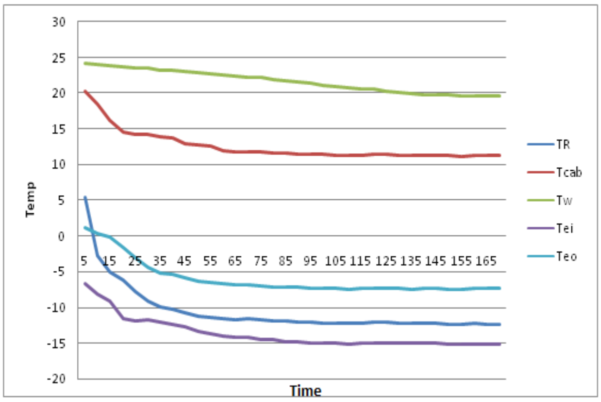

Figure 12: Time Vs TR, Tw, Tcab, Tei, Teo shows that cabinet water temperature is obtained higher and evaporator inlet temperature is obtained very low as compared to with each other at 50lit water inside cabinet condition.

3.3 Comparative analysis of R-134a and HC-12a refrigerant

At no load condition

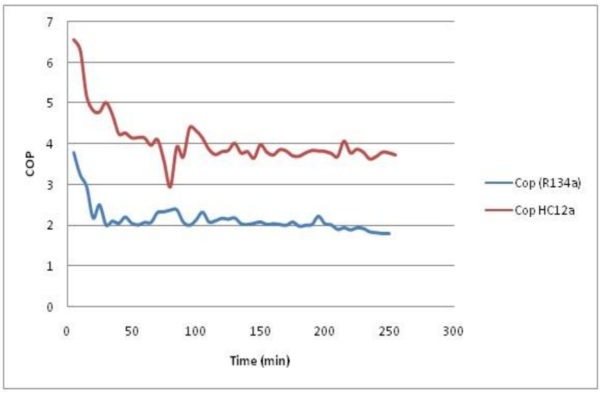

Figure 13: shows that HC-12a shows higher cop as compared to ref. R-134a. HC-12a ref. occurs in the range of 6.57 to 2.94 and R-134a in the range of 3.77 to 1.8.

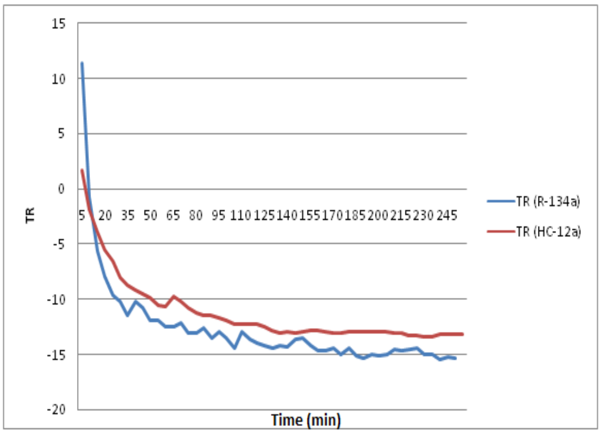

Figure 14: shows the observed values of freezer temperature for R-134a and mixed refrigerants (HC-12a). R-134a shows lower temp to -15.4oC as compared to the mixed refrigerants.

At 60 watt condition

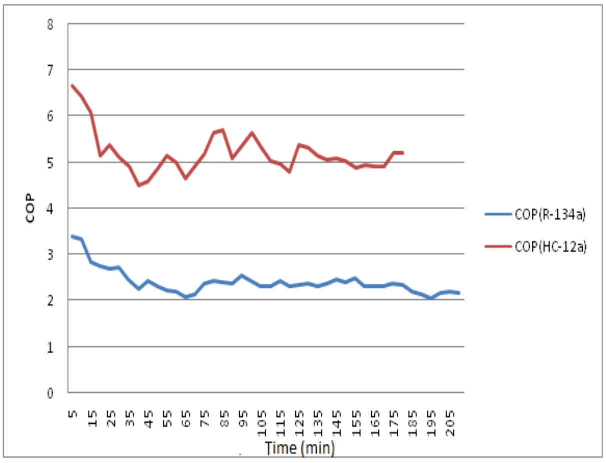

Figure 15: shows that the observed values cop for R-134a and HC-12a. COP of mixed ref. (HC-12a) shows more cop compared to ref. R-134a.

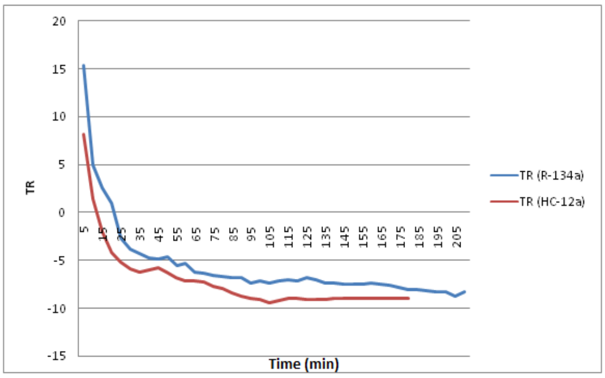

Figure 16: shows the observed values of freezer temperature for R-134a Vs mixed refrigerants (HC-12a). HC-12a shows near about equally temp as compared to the R-134a at 60watt bulb condition.

At 120 watt condition

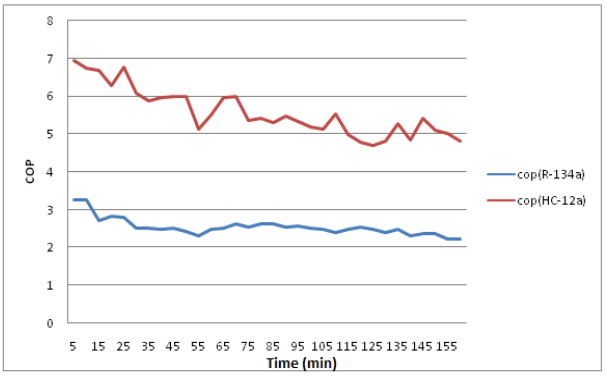

Figure 17: shows that the observed values cop(HC-12a) Vs cop(R-134a) shows higher cop of HC-12a as compared to R-134a at the initial cond.

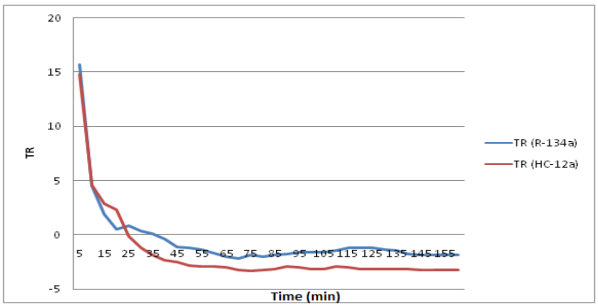

Figure 18: shows the observed values of freezer temperature for R-134a and mixed refrigerants (HC-12a). Mixed refrigerants shows lower temp to -3.2oC as compared to the R-134a at 120watt condition.

At 160 watt condition

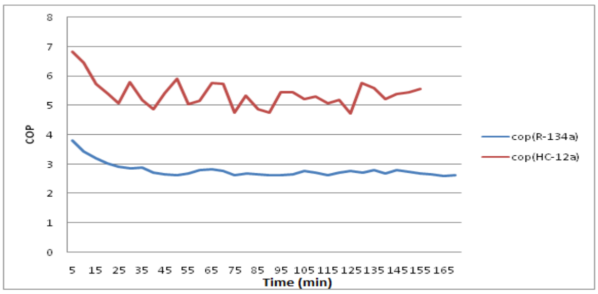

Figure 19: shows that the observed values of cop for R-134 Vs HC-12a at diff temp. cop of the mixed ref. shows more cop compared to ref R-134a.

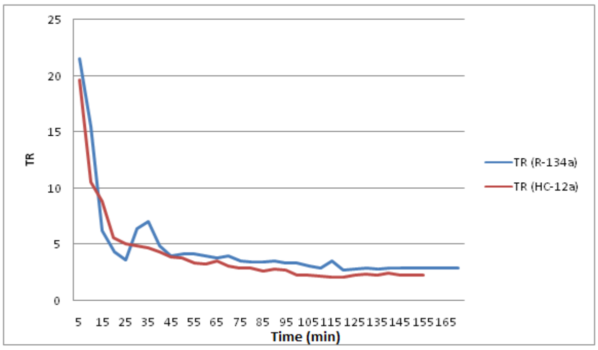

Figure 20: shows the observed values of freezer temperature for R-134a and mixed refrigerants (HC-12a). HC-12a shows near about equally temp as compared to the R-134a at 160watt bulb condition.

At 50 lit water condition

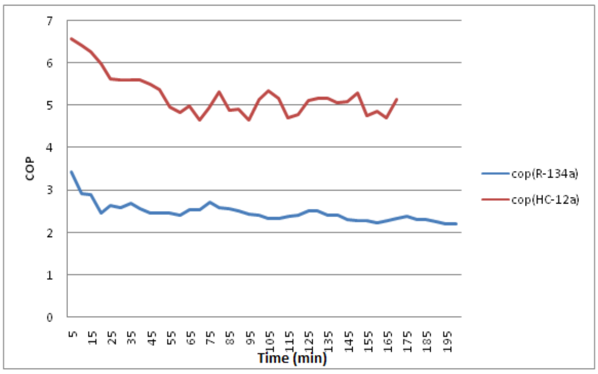

Figure 21: shows that the observed values of cop for R-134 Vs HC-12a. HC-12a has higher cop as compared to ref. R-134a at initial condition at 50lit cabinet water cond.

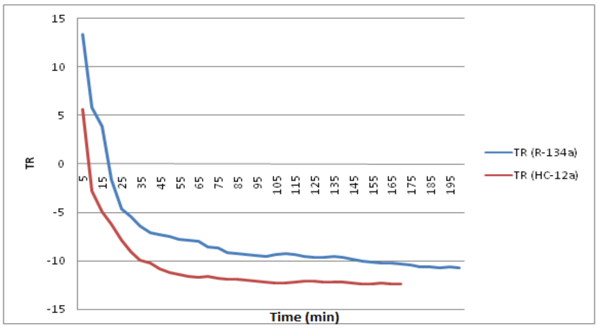

Figure 22: shows the observed values of freezer temperature for R-134a Vs mixed refrigerants (HC-12a). Mixed refrigerants shows lower temp as compared to the R-134a at 50lit cabinet water condition.

3.4 Comparative analysis of COP for R-134a and HC-12a refrigerant

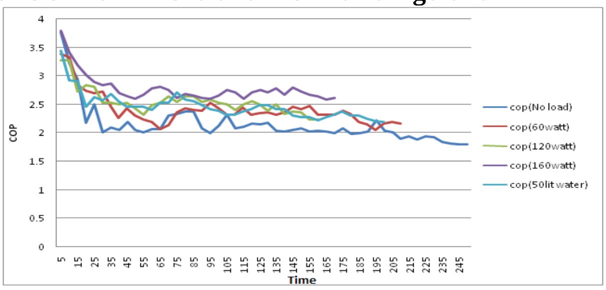

Figure 23: Time Vs COP of no load, 60watt, 120watt, 160watt, 50lit cabinet water condition shows that all cops at different conditions are comparatively higher at starting periods and also different type of cop occurs in between 3.77 to 1.8.

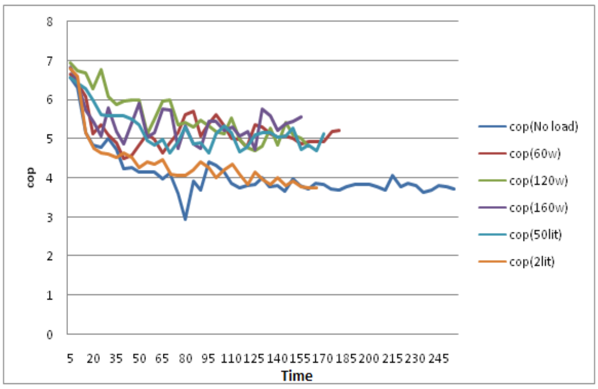

Figure 24: Time Vs COP of no load, 60watt, 120watt, 160watt, 50lit cabinet and 2lit freezer water condition shows that all cops at different conditions are comparatively higher at starting periods and all different type of cop occurs in the range of 6.96 to 2.97.

IV. CONCLUSION

As per the Kyoto and Montreal protocols, the harmful refrigerants are to be phased out and are to be replaced with alternate environmental friendly refrigerants with zero ozone depletion potential (ODP) and negligible global warming potential (GWP), to replace R-12 and R134a in domestic refrigerator

1. Hydrocarbons blends may replace R-134a without any system modifications.
2. COP of the system is improved with reduced energy consumption.
3. Hydrocarbon refrigerants are compatible with mineral oils (commonly used lubricants).
4. Hydrocarbon technology provides a simple, sustainable and cost-effective solution for replacing R-134a in the domestic refrigeration subsector in developing countries.
5. Chemical and thermodynamics properties of hydrocarbon meet the requirement of a good refrigerant. 6. Some standards allow the use HCs as refrigerant if small amount of refrigerant is used due the latent heat of vaporization.
7. The only disadvantage associated with this gas is its flammability, which can be an obstacle in its implementation. This problem can be solved by proper design of the refrigerator..

V. FUTURE SCOPE

Hydrocarbons blends may replace R-134a without any system modifications and COP of the system is improved with reduced energy consumption. So our future intension is that increase the requirement of HC-12a as a refrigerant in all types of domestic refrigerators and air conditioning system in near future. Due to the zero ozone depletion potential (ODP) and negligible global warming potential (GWP), environments becomes a safe and sweets. In develop countries HC-12a as a refrigerant use in car air conditioning as well as industrial air conditioning.

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