EXPERIMENTAL PERFORMANCE CHARACTER AND ANALYSIS OF HYDROCARBON REFRIGERATION SYSTEM

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ABSTRACT

Our project 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.

KEYWORDS: *hc refrigerant, natural refrigerant.*

INTRODUCTION

The main aim of our project is to prevent the ozone depletion by replacing the CFC's, HCFC's, HFC's with the HC. The modern refrigerator and air conditioning system uses the HFC-134a (1,1,1,2-tetrafluroethane) has an refrigerant it contains fluro-carbon which causes ozone depletion and hazards to the living organisms.(HC-12a or refrigerant-12a) is the natural, non-toxic which prevents the ozone depletion and global warming.HC-12a is the mixture of hydrocarbons mainly propane (R-290) and iso-butane (R-600a).The natural non-toxic refrigerant includes air, water, CO_2, ammonia,hydrocarbon.HC refrigerant are 50% more efficient condenser of heat than flurocarbon operating pressure of about 25% lower, due to low pressure wear and tear at compressor and pipelines can be reduced.

1.1 THROTTLING DEVICE

Capillary tube is one of the most commonly used throttling devices in the refrigeration and the air conditioning systems. The capillary tube is a copper tube of very small internal diameter. It is of very long length and it is coiled to several turns so that it would occupy less space. The internal diameter of the capillary tube used for the refrigeration and air conditioning applications varies from 0.5 to 2.28 mm (0.020 to 0.09 inches). Capillary tube used as the throttling device in the domestic refrigerators, deep freezers, water coolers and air conditioners

In the normal working conditions of the refrigeration plant there is drop in pressure of the refrigerant across the capillary but when the plant stops the refrigerant pressure across the two sides of the capillary equalize. Due to this reason when the compressor restarts there won't be much load on it. Also, due to this reason one cannot over-charge the refrigeration system with the refrigerant and no receiver is used.

1.2 COMPRESSOR

A compressor is a mechanical device that increases the pressure of a gas by reducing its volume. An air compressor is a specific type of gas compressor. Compressors are similar to pumps both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas. Liquids are relatively incompressible; while some can be compressed, the main action of a pump is to pressurize and transport liquids. The following types of compressor are as follows

- 1.2.1 Reciprocating Compressor
- 1.2.2 Rotary screw compressor
- 1.2.3 Rotary vane compressor
- 1.2.4 Scroll compressor
- 1.2.5 Diaphragm compressor

A positive displacement compressor is a system which compresses the air by the displacement of a mechanical linkage reducing the volume (since the reduction in volume due to a piston in thermodynamics is considered as positive displacement of the piston)

1.2.1 RECIPROCATING COMPRESSOR

A reciprocating compressor or piston compressor is a positive-displacement compressor that uses pistons driven by a crankshaft to deliver gases at high pressure.

The intake gas enters the suction manifold, then flows into the compression cylinder where it gets compressed by a piston driven in a reciprocating motion via a crankshaft, and is then discharged. Applications include oil refineries, gas pipelines, chemical plants, natural gas processing plants and refrigeration plants. One specialty application is the blowing of plastic bottles made of polyethylene terephthalate (PET).

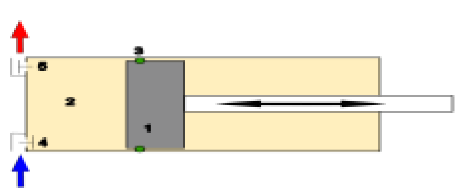


Fig 1.2.1 Reciprocating compressor

1.2.2 ROTARY VANE COMPRESSOR

A rotary vane compressor is a positive-displacement pump that consists of vanes mounted to a rotor that rotates inside a cavity. In some cases these vanes can have variable length and/or be tensioned to maintain contact with the walls as the pump rotates. It was invented by Charles C. Barnes of Sackville, New Brunswick, who patented it on June 16, 1874.

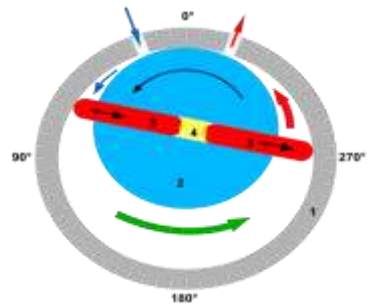


Fig 1.2.3 Rotary vane compressor

1.2.3 SCROLL COMPRESSOR

A scroll compressor is a device for compressing air or refrigerant. It is used in air conditioning equipment, as an automobile supercharger (where it is known as a scroll-type supercharger) and as a vacuum pump. Many residential central heat pump and air conditioning systems and a few automotive air conditioning systems employ a scroll compressor instead of the more traditional rotary, reciprocating, and wobble-plate compressors.

A scroll compressor operating in reverse is known as a scroll expander , and can be used to generate mechanical work from the expansion of a fluid, compressed air or gas. A scroll compressor uses two interleaving scrolls to pump, compress or pressurize fluids such as liquids and gases. The vane geometry may be involute, Archimedean spiral, or hybrid curves.

Often, one of the scrolls is fixed, while the other orbits eccentrically without rotating, thereby trapping and pumping or compressing pockets of fluid between the scrolls. Another method for producing the compression motion is co-rotating the scrolls, in synchronous motion, but with offset centers of rotation. The relative motion is the same as if one were orbiting.

Fig 1.2.4 Scroll compressor

1.2.4 DIAPHRAGM COMPRESSOR

A diaphragm compressor is a variant of the classic reciprocating compressor with backup and piston rings and rod seal. The compression of gas occurs by means of a flexible membrane, instead of an intake element. The back and forth moving membrane is driven by a rod and a crankshaft mechanism. Only the membrane and the compressor box come in touch with pumped gas. For this reason this construction is the best suited for pumping toxic and explosive gases. The membrane has to be reliable enough to take the strain of pumped gas. It must also have adequate chemical properties and sufficient temperature resistance.

Fig 1.2.5 Diaphragm compressor

1.3 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 transferred to the surrounding environment. Condensers can be made according to numerous designs, and come in many sizes ranging from rather small (hand-held) to very large (industrial-scale units used in plant processes). For example, a refrigerator uses a condenser to get rid of heat extracted from the interior of the unit to the outside air. Condensers are used in air conditioning, industrial chemical processes such as distillation, steam power plants and other heat-exchange systems. Use of cooling water or surrounding air as the coolant is common in many condensers. There are some of the types which are as follows

- **1.3.1** Air cooled condenser.
- **1.3.2** Water cooled condenser.

Fig 1.3 Condenser

1.3.1 AIR COOLED CONDENSER

Air cooled condensers directly condense exhaust steam from the steam turbine and return condensate to the boiler without water loss. They are frequently used in electrical power plants and waste to energy plants of all sizes.An Air Cooled Condenser (ACC) is made of modules arranged in parallel rows. Each module contains a number of fin tube bundles. An axial flow, forced-draft fan located in each module forces the cooling air across the heat exchange area of the fin tubes.

It is a method of dissipating heat. It works by expanding the surface area or increasing the flow of air over the object to be cooled, or both. An example of the former is to add cooling fins to the surface of the object, either by making them integral or by attaching them tightly to the object's surface (to ensure efficient heat transfer). In the case of the latter, it is done by using a fanblowing air into or onto the object one wants to cool. The addition of fins to a heat sink increases its total surface area, resulting in greater cooling effectiveness.

Fig 1.3.1 Air cooled condenser

1.3.2 WATER COOLED CONDENSER

Water cooling is a method of heat removal from components and industrial equipment. Water may be a more efficient heat transfer fluid where air cooling is ineffective. In most occupied climates water offers the thermal conductivity advantages of a liquid with unusually high specific heat capacity and the option of evaporative cooling. Low cost often allows rejection as waste after a single use, but recycling coolant loops may be pressurized to eliminate evaporative loss and offer greater portability and improved cleanliness. Unpressurized recycling coolant loops using evaporative cooling require a blowdown waste stream to remove impurities concentrated by evaporation. Disadvantages of water cooling systems include accelerated corrosion and maintenance requirements to prevent heat transfer reductions from biofouling or scale formation. Chemical additives to reduce these disadvantages may introduce toxicity to wastewater. Water cooling is commonly used for cooling automobile internal combustion engines and large industrial facilities such as nuclear and steam electric power plants, hydroelectricgenerators, petroleum refineries and chemical plants. Other uses include cooling the barrels of machine guns, cooling of lubricant oil in pumps; for cooling purposes in heat exchangers; cooling products from tanks or columns, and recently, cooling of various major components inside high-end personal computers such as CPUs, GPUs, and motherboards. The main mechanism for water cooling is convective heat transfer.

Fig 1.3.2 Water cooled condenser

Water is inexpensive, non-toxic, and available over most of the earth's surface. Liquid cooling offers higher thermal conductivity than air cooling. Water has unusually high specific heat capacity among commonly available liquids at room temperature and atmospheric pressure allowing efficient heat transfer over distance with low rates of mass transfer.

1.4 EVAPORATOR

An Evaporator is a device in a process used to turn the liquid form of a chemical substance such as water into its gaseous-form/vapor. The liquid is evaporated, or vaporized, into a gas form of the targeted substance in that process. The solution containing the desired product is fed into the evaporator and passes across a heat source. The applied heat converts the water in the solution into vapor. The vapor is removed from the rest of the solution and is condensed while the now-concentrated solution is either fed into a second evaporator or is removed. The evaporator, as a machine, generally consists of four sections. The heating section contains the heating medium, which can vary. Steam is fed into this section. The most common medium consists of parallel tubes but others have plates or coils typically made from copper or aluminium. The concentrating and separating section removes the vapor being produced from the solution. The condenser condenses the separated vapor, then the vacuum or pump provides pressure to increase circulation.

One kind of evaporator is a kind of radiator coil used in a closed compressor driven circulation of a liquid coolant. That is called an air-conditioning system (A/C) or refrigeration system to allow a compressed cooling chemical, such as R-22 (Freon) or R-410A, to evaporate/vaporize from liquid to gas within the system while absorbing heat from the enclosed cooled area, for example a refrigerator or rooms indoors, in the process. This works in the closed A/C or refrigeration system with a condenser radiator coil that exchanges the heat from the coolant, such as into the ambient environment.

Fig 1.4 Evaporator

1.5 REFRIGERANT

1.5.1 EXSISTING REFRIGERANT: (HFC-134a)

1,1,1,2-Tetrafluoroethane (also known as norflurane (INN), R-134a, Freon 134a, Forane 134a, Genetron 134a, Florasol 134a, Suva 134a, or HFC-134a) is a haloalkane refrigerant with thermodynamic properties similar to R-12 (dichlorodifluoromethane) but with insignificant ozone depletion potential and a somewhat lower global warming potential (1,430, compared to R-12's GWP of 10,900). It has the formula CH_2FCF_3 and a boiling point of −26.3 °C (−15.34 °F) at atmospheric pressure. R-134a cylinders are colored light blue. Attempts at phasing out its use as a refrigerant with substances that have lower global warming potential, such as HFO-1234yf, are underway. It is also being considered as an organic solvent suitable for extraction of flavor and fragrance compounds, as a possible alternative to other organic solvents and supercritical carbon dioxide. It can also be used as a solvent in organic chemistry, both in liquid and supercritical fluid. It is used in the resistive plate chamberparticle detectors in the Large Hadron Collider. It is also used for other types of particle detectors, e.g. some cryogenic particle detectors.

It can be used as an alternative to sulfur hexafluoride in magnesium smelting as a shielding gas. 1,1,1,2-Tetrafluoroethane is also being considered as an alternative to sulfur hexafluorideas a dielectric gas. Its arc-quenching properties are poor, but its dielectric properties are fairly good. It is a non-flammable gas used primarily as a "high-temperature" refrigerant for domestic refrigeration and automobile air conditioners. 1,1,1,2-Tetrafluoroethane has also been used to cool computers in some overclocking attempts. It is the refrigerant used in plumbing pipe freeze kits. It is also commonly used as a propellant for airsoft airguns. The gas is often mixed with a silicone-based lubricant.

Fig 1.5.1 HFC-134a Refrigerant

1.5.2 REPLACEABLE REFRIGERANT: (HC-12a)

HC-12a, also called ES-12a , and hydrocarbon blend B, is a "drop-in" replacement refrigerant for Freon-12 and to a lesser extent, R-134a. HC-12a is a mixture of hydrocarbons, specifically propane (R-290) and isobutane (R-600a), and is therefore considered nearly non-ozone-depleting when compared to dichlorodifluoromethane (R-12, Freon-12) or 1,1,1,2-tetrafluoroethane (R-134a). The mixture can be used in refrigeration systems designed for R-12. HC-12a provides better cooling than an R-12 system retrofitted to R-134a, with much greater energy efficiency as well. Unlike R-134a, HC-12a is completely compatible with the hoses and oils used in R-12 systems, making the conversion much easier to accomplish. HC-12a is also patent-free due to its non-synthetic nature.

Because of its flammability, it is illegal to replace R-12 with HC-12a in the United States. It is not illegal to purchase HC-12a, or to use it in refrigeration systems that were not originally charged with R-12, except for in certain states that prohibit the use of flammable refrigerants in automobiles.

Some advantages to using the HC-12a mixture over retrofitting to R-134a are cost and labor. Since HC-12a is a "drop-in" replacement, no seals need to be replaced and minimal effort has to be put into changing the refrigeration system around. Disadvantages to using the HC-12a mixture in R-12 systems is that it is potentially dangerous and is illegal in the United States. The refrigerant used is propane and other hydrocarbons which are flammable. However, it should also be noted that R-134a (and other refrigerants) are just as flammable when mixed with refrigerant oil, yet the quantity of refrigerant and oil in a typical system is so low that the danger in any case is minimal.

Fig 1.5.2 HC-12a Refrigerant

1.6 PRESSURE GAUGE

Pressure measurement is the analysis of an applied force by a fluid (liquid or gas) on a surface. Pressure is typically measured in units of force per unit of surface area. Many techniques have been developed for the measurement of pressure and vacuum. Instruments used to measure and display pressure in an integral unit are called pressure gauges or vaccum gauges. A manometer (not to be confused with nanometer) is a good example, as it uses a column of liquid to both measure and indicate pressure. Likewise the widely used Bourdon gauge is a mechanical device, which both measures and indicates and is probably the best known type of gauge.

A vacuum gauge is a pressure gauge used to measure pressures lower than the ambient atmospheric pressure, which is set as the zero point, in negative values (e.g.: −15 psig or −760 mmHg equals total vacuum). Most gauges measure pressure relative to atmospheric pressure as the zero point, so this form of reading is simply referred to as "gauge pressure". However, anything greater than total vacuum is technically a form of pressure.

Fig 1.6 Pressure gauge

1.7 THERMOCOUPLE

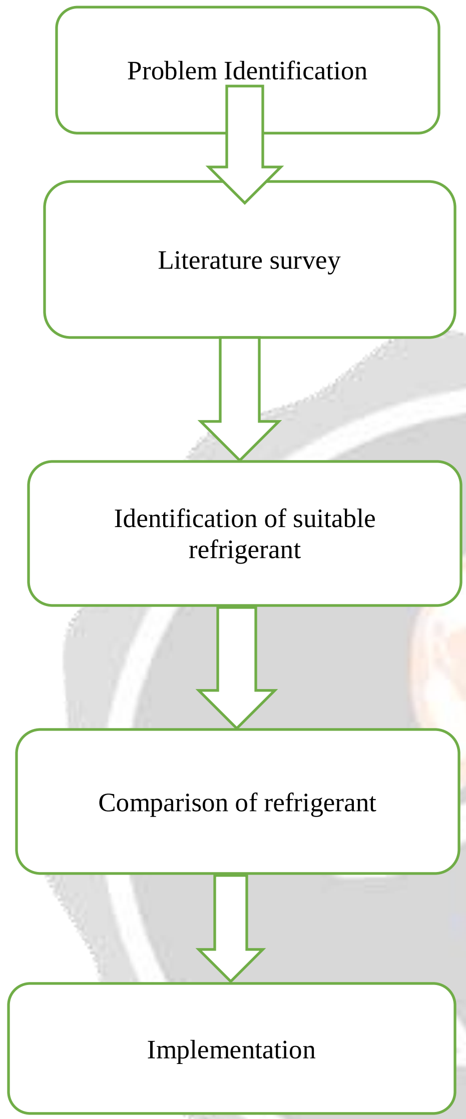
A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming electrical junctions at differing temperatures. A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Thermocouples are a widely used type of temperature sensor. Commercial thermocouples are inexpensive, interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures. In contrast to most other methods of temperature measurement, thermocouples are self powered and require no external form of excitation. The main limitation with thermocouples is precision; system errors of less than one degree Celsius (°C) can be difficult to achieve.

Fig 1.7 Thermocouple

Thermocouples are widely used in science and industry. Applications include temperature measurement for kilns, gas turbine exhaust, diesel engines, and other industrial processes. Thermocouples are also used in homes, offices and businesses as the temperature sensors in thermostats, and also as flame sensors in safety devices for gas-powered appliances.

The voltage generated at a single junction of two different types of wire is what is of interest as this can be used to measure temperature at very high and low temperatures. The magnitude of the voltage depends on the types of wire being used.

2. METHODOLOGY



3. WORKING PRINCIPLE

The principle on how does a refrigerator work is pretty simple. Gases get hotter when you compress them into less volume because you have to work to push their energetic molecules together. When you expand a gas, it is suddenly able to occupy much more volume. The heat energy its molecules contain is now divided over a much bigger volume of space, so the temperature of the gas falls (it gets cooler). The other principle at work in a refrigerator is that when you have two things that are different temperatures that touch or are near each other, the hotter surface cools and the colder surface warms up. This is a law of physics called the Second Law of Thermodynamics.

Here is how the components of the refrigeration cycle interact to cool your food:

- The compressor constricts the refrigerant vapor, raising its pressure and temperature, and pushes it into the coils of the condenser on the outside of the refrigerator.
- When the hot gas in the coils of the condenser meets the cooler air temperature of the kitchen, it becomes a liquid.

- Now in liquid form at high pressure, the refrigerant cools down as it flows through the expansion valve into the evaporator coils inside the freezer and the fridge.
- The refrigerant absorbs the heat inside the fridge when it flows through the evaporator coils, cooling down the air inside the fridge.
- Last, the refrigerant evaporates to a gas due to raised temperature, and then flows back to the compressor, where the cycle starts all over again.

4. PROPERTY COMPARISON OF REFRIGERANTS

DESCRIPTION	HFC-134a	HC-12a
Chemical Formula	CH_2-F-CF_3	CH_3-CH_2-CH_3/CH_3-CH-CH_3
Composition by mass(%)	Pure fluid	Pure fluid
Molecular weight(kg/kmol)	102.0	50.14
Boiling point(oC)	-26.07	-29.8
Critical pressure(MPa)	4.0593	4.128
Critical temperature(oC)	101.06	-156.45
ODP	0	0
GWP(100 years)	1300	3
Freezing point(oC)	-142	-183
Atmospheric life	16 years	< 1 year
Toxic thermal decomposition	Hydrofluoride gas	None
Auto-ignition(oC)	751	891

5.EXPERIMENTAL SETUP

Fig 5 Experimental Setup

6. RESULTS AND DISCUSSION

EXSISTING REFRIGERANT HFC-134a

6.1.1 Observations for R-134a as a refrigerant at no load condition:

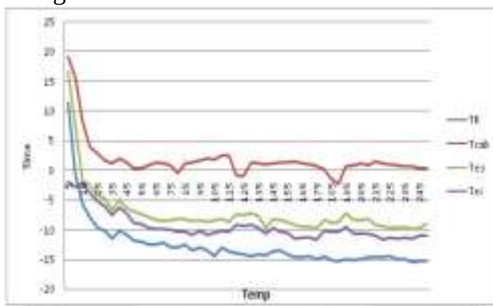


Fig 6.1.1 Time Vs TR, Tcab, Teo, Tei shows that at no load condition freezer temperature obtained is very low as compared to other temperature

6.1.2 At 60watt condition:

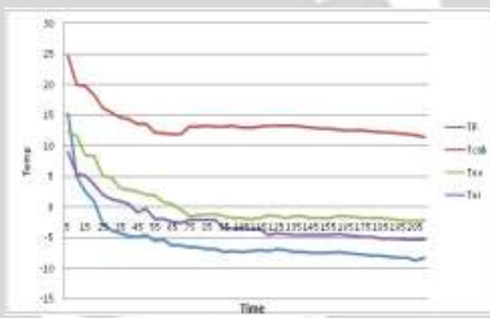


Fig 6.1.2 Time Vs T_R, Tcab, Teo, Tei shows that at 60w condition freezer temperature obtained is very low as compared to other temperature

6.1.3 At 120watt condition:

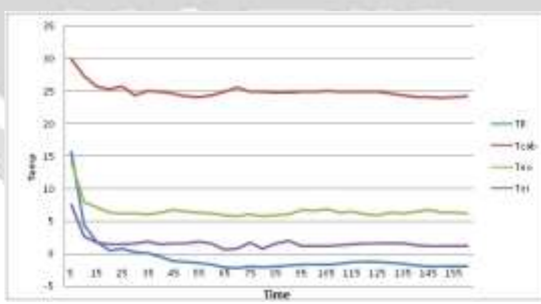


Fig 6.1.3 Time Vs T_R, Tcab, Teo, Tei shows that at 120watt condition freezer temperature obtained is low as compared to other temperature.

6.1.4 At 270mm water cabinet condition :

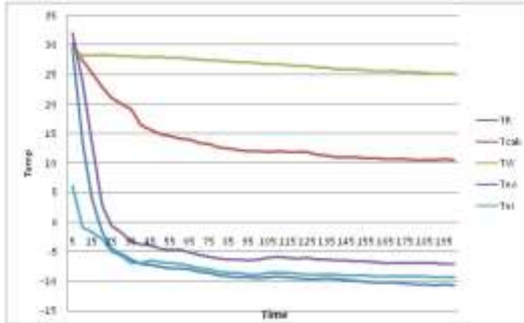


Fig 6.1.4 Time Vs T_R, Tcab, Teo, Tei and Tw shows that at 270mm water inside cabinet condition freezer temp. obtained is comparatively low as compared to other temperature.

6.2 REPLACEABLE REFRIGERANT HC-12a

6.2.1 Observations for HC-12a as a refrigerant at no load condition:

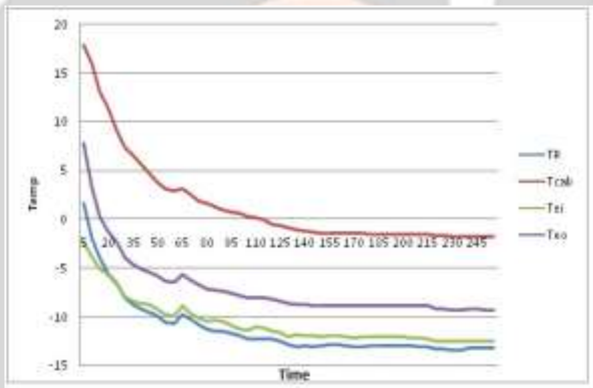


Fig 6.2.1 Time Vs TR, Tcab, Tei and Teo shows that freezer temperature is obtained very low as compared to other at no load condition.

6.2.2 At 60watt condition:

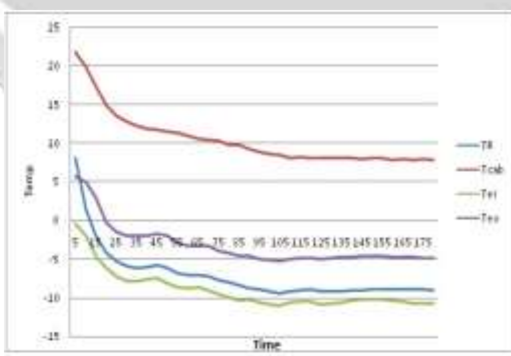


Fig 6.2.2 Time Vs TR, Tcab, Tei and Teo shows that cabinet temperature is obtained higher due to 60watt bulb cond. and evaporator inlet temperature is obtained very low as compared to with each other at 60watt condition.

6.2.3 At 120watt condition:

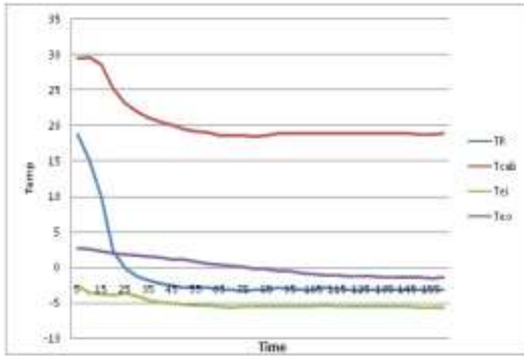


Fig 6.2.3 Time Vs TR, Tcab, Tei and Teo shows that cabinet temperature is obtained higher due to 120watt bulb condition as compared to other temperature.

6.2.4 At 270mm water cabinet condition:

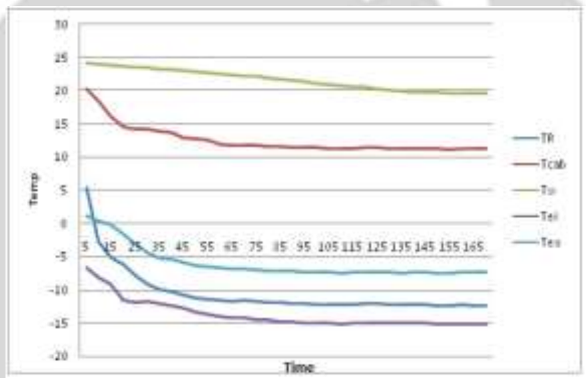


Fig 6.2.4 Time Vs TR, Tw, Tcab, Tei, Teo shows that cabinet water temperature is obtained higher and evaporator inlet temperature is obtained very low as compared to with each other at 270mm water inside cabinet condition.

6.3 COMPARATIVE ANALYSIS OF REFRIGERANTS

HFC-134a and HC-12a:

6.3.1 At no load condition:

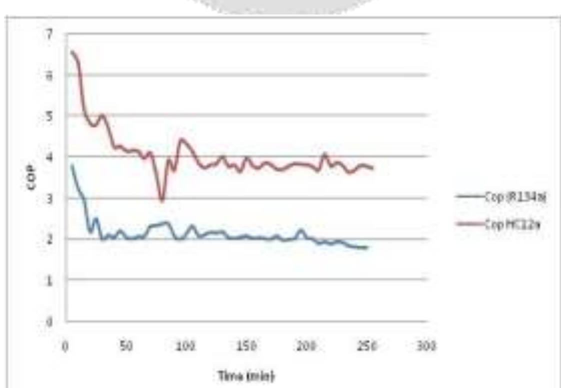


Fig 6.3.1 shows that HC-12a shows higher cop as compared to ref. R-134a. HC-12a ref. occurs in the range of 6.57 to 2.94 and R-134a in the range of 3.77 to 1.8.

6.3.2 At 270mm water condition:

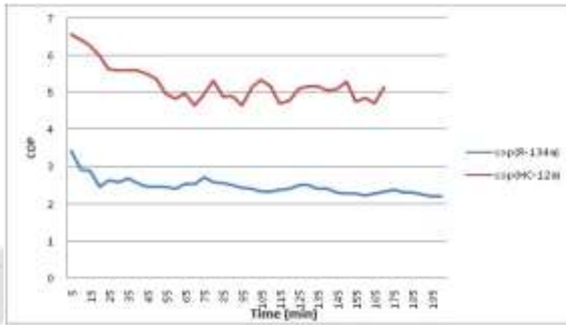


Fig 6.3.2 shows that the observed values of cop for R-134 Vs HC-12a. HC-12a has higher cop as compared to ref. R-134a at initial condition at 270mm cabinet water cond.

6.4 COMPARATIVE ANALYSIS OF COP

6.4.1 HFC-134a:

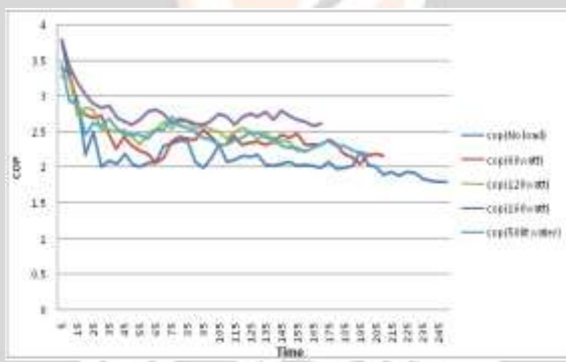


Fig 6.4.1 Time Vs COP of no load, 60watt, 120watt, 270mm cabinet water condition shows that all cops at different conditions are comparatively lower .

6.4.2 HC-12a:

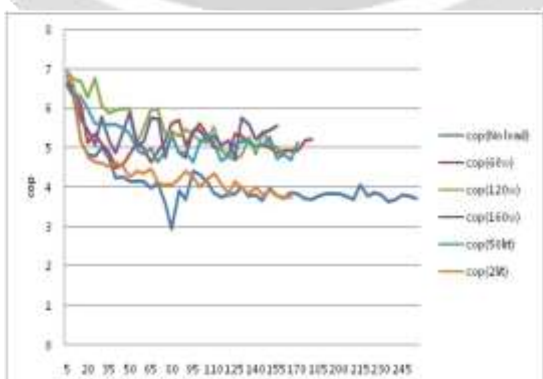


Fig 6.4.2 Time Vs COP of no load, 60watt, 120watt, 270mm cabinet and 2lit freezer water condition shows that all cops at different conditions are comparatively higher .

7. CONCLUSION

As we know that 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. The above project is made with pre planning, so that it reduces the ozone depletion potential as well as global warming potential. The project "EXPERIMENTAL PERFORMANCE CHARACTERISTICS AND ANALYSIS OF HYDOCARBON REFRIGERATION SYSTEM" is done with the hope that it it reduces the ozone depletion potential as well as global warming potential with performance and efficiency.

8. SCOPE OF HC REFRIGERATION SYSTEM

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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