Nanorefrigerant effect on performance of domestic refrigerator: A Review

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Abstract: Vapor compression refrigeration systems consume high-grade energy and contribute to global warming and ozone layer depletion due to the environmentally unfriendly refrigerants. The use of nanorefrigerants offer good performance in domestic refrigerator in terms of energy consumption and cooling time. In this study, a review of the previous studies carried out with the use of nanorefrigerants in refrigeration is presented. An attempt has been made to cover the current status, possibilities, and problems related to the use of nanorefrigerants as alternative refrigerants. Nanorefrigerant properties, environmental impact and characteristic are also presented. Results showed that nanorefrigerants can offer proper refrigerants as compare to hydrocarbons from the standpoint of environment impact, energy efficiency, Energy consumption and compressor discharge temperatures.

Keywords **- Nanorefrigerant, Domestic refrigerator, Power consumption, Cooling time.**

I. INTRODUCTION

1.1 DOMESTIC REFRIGERATOR:

A domestic refrigerator has become one of the most important household appliances all over the world. More than millions of domestic refrigerators are manufactured by many company every year. A domestic refrigerator is small cold storage where several food products such as ice cream, meat, fish, milk, fruits, vegetables, water etc. can be stored at reduced temperatures. The most common domestic refrigerator uses a vapour compression refrigeration system for maintaining required storage conditions, even though many refrigerators use the principle of triple fluid vapour absorption refrigeration system. Domestic refrigerators are available in many sizes and designs. The domestic refrigerator is specified by the storage volume (gross or net), like a 300 litre refrigerator means a domestic refrigerator with an internal storage volume of 300 litres. The domestic refrigerators are available in many sizes from about 100 litres to about 600 litres. Currently, most of these units use either HFC-134a or hydrocarbons as refrigerants. They use hermetic compressor with a capillary tube as an expansion device. The condenser of small refrigerators are of natural convection type, while larger refrigerators may have a fan for forced air circulation over the condenser.

1.1.1 Internal parts of the Domestic Refrigerator

The internal parts of the refrigerator are ones that do actual working of the refrigerator. Some of the internal parts are located at the back of the refrigerator and some inside the main compartment of the refrigerator. Some internal parts of the domestic refrigeratror are:

1)Refrigerant: The refrigerant flows through all the internal parts of the refrigerator. It is the refrigerant by which the cooling effect occurred in the evaporator. It absorbs the heat from the substance to be cooled in the evaporator and release it to the atmosphere via condenser.

2) Compressor: The compressor is located at the back of the refrigerator and in the bottom area. The compressor sucks the refrigerant from the evaporator and discharges it at high pressure and temperature. The compressor is run by the electric motor and it is the major power consuming component of the refrigerator.

3) Condenser: The condenser is the thin coil of tube of copper located at the back of the refrigerator. The refrigerant from the compressor enters the condenser where it is cooled by the atmospheric air thus losing heat absorbed by it in the evaporator and the compressor. Fins are placed in the condenser for increasing heat transfer rate.

4) Expansion valve or the capillary: The refrigerant leaving the condenser enters the expansion valve. When the refrigerant is passed through the capillary its pressure and temperature decreases suddenly.

5) Evaporator or Chiller: The refrigerant at very low pressure and temperature enters the evaporator or the freezer. Generally in domestic refrigerators the plate types of evaporator is used. The refrigerant takes the heat from the substance to be cooled in the evaporator and evaporated then it is sucked by the compressor. This cycle keeps on repeating.

6) Thermostat: To control the temperature inside the refrigerator thermostat is used and sensor of it is connected to the evaporator. The thermostat setting can be done by the round knob inside the refrigerator compartment. When the set temperature is reached inside the refrigerator the thermostat stops the electric supply to the compressor and compressor stops and when the temperature decreases below certain level it restarts the supply to the compressor.

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

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

1.1.2 External parts of the Domestic Refrigerator

The external parts of the compressor are the parts that can be seen externally and used for the many purposes.

1) Freezer compartment: The food items that are to be placed at the freezing temperature are stored in the freezer compartment. The temperature here is below zero degree Celsius so the water and many other fluids freeze in this compartment.

2) Thermostat control: The thermostat control consists of the round knob with the tempera- ture scale that maintain the required temperature inside the refrigerator. Proper setting of the thermostat as per the requirements save the lots of refrigerator electricity bills.

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

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

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

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

1.2 HISTORY OF REFRIGERANT:

Refrigerant:

Refrigerants are the working medium used in refrigerating systems which evaporates by absorbing the heat from the space that is to be cooled and producing the cooling effect.

First Generation Refrigerants

At the starting of 19th century mechanical refrigeration were characterized by use of natural refrigerants. Refrigerators that were built in the late 1800s to 1929 used the first generation refrigerants like methyl chloride, ammonia and sulphur dioxide. The common refrigerants for the first hundred years included whatever worked and whatever was available. Approximately all the first generation refrigerants were flammable, toxic or both and highly reactive.

Ammonia

It is denoted by R717 and is also a very old refrigerant used in vapour compression and ab- sorption refrigeration systems. They have a lower molecular weight, wide range of working temperature because of its high critical point, high latent heat of vapourization and easy leak detection. It is highly toxic, highly irritating and flammable.

Sulphur Dioxide

Sulphur dioxide is generally used in 1920s and 1930s and it has been replaced first by methyl chloride and later by more favourable fluorocarbon refrigerants. It is highly toxic but non- explosive and non-flammable. It is non-corrosive in pure state but when it combines with mois- ture it forms sulphurous acids and sulphuric acids which are highly corrosive.

Methyl Chloride

Methyl chloride was first used in 1878. Methyl chloride is a colourless extremely flammable gas with a mildly sweet odour. Methyl chloride is corrosive to aluminium, zinc, magnesium.

Second Generation Refrigerants

The second generation refrigerants were found by a shift to chlorofluoro chemicals for safety and durability. They disregarded compounds that are unstable, toxic, yielding insufficient volatility and inert gases based on their low boiling point. In 1928, Midgley and his colleagues done crit- ical observations of flammability and toxicity of compounds containing elements like carbon, nitrogen, oxygen, sulphur, hydrogen, fluorine, chlorine and bromine. Their first publication was on fluorochloro refrigerants and it showed how the variation of chlorination and fluorination of hydrocarbons influences boiling point, flammability and toxicity of the refrigerants. Thus CFC refrigerants used as the second generation of refrigerants. CFC is a non-toxic, non-flammable gas with high mass. It is a good refrigerant because it can be compressed easily to liquid and rejects lots of heat when it evaporates.

R-11

R 11 is non-flammable and non-explosive. So it can be considered as safe. It is used in the applications like air conditioning of small buildings, factories, departmental stores, theatres etc.

R-12

R12 is a highly versatile refrigerant that is used for wide range of refrigeration and air con- ditioning applications. R12 is non-toxic, non-flammable, and non-explosive. It is suitable for wide range of operating conditions.

Third Generation Refrigerants

The third generation refrigerants based on hydro chlorofluorocarbon (HCFC) and hydro fluoro- carbon (HFC) have been developed to replace second generation refrigerants. The advantages of it is same as CFC without damaging the EarthâĂŹs ozone layer, but they were developed before the environmental impact of fluorine was fully understood. This effect has been termed as Global Warming Potential(GWP).

Next Generation Refrigerants

HCFC/HFC such as R22 and R134a are on the way to phase-out due to environmental concern. Under medium and long term refrigerants like HFC chlorine free and their blend, low GWP refrigerant (R1234yf,1234ze) and halogen free refrigerant (natural refrigerant) are looking as the feasible options for future refrigerant at current position.

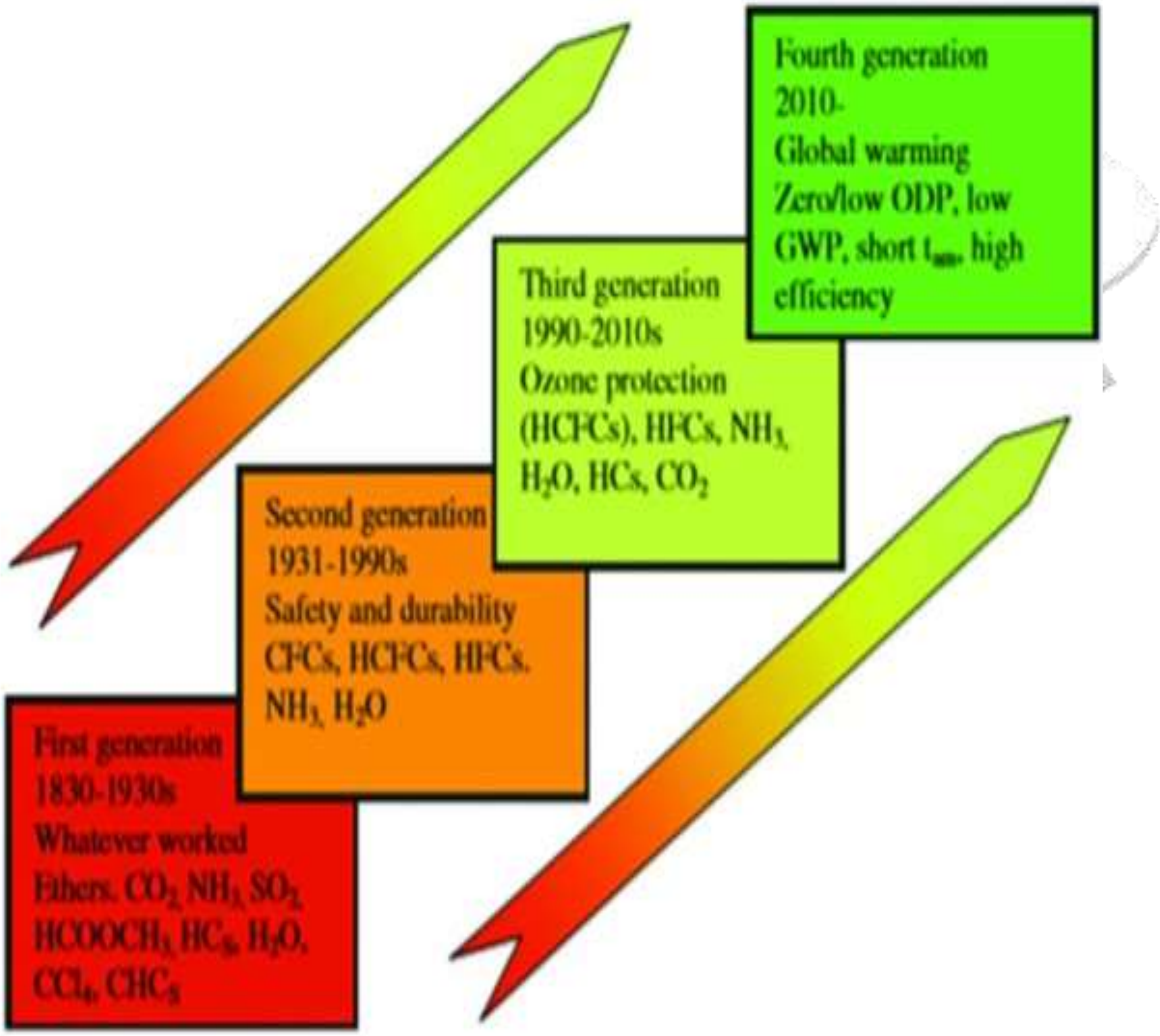

Figure 1.1: Generation ofRefrigerant

Table 1.1: Environment properties of Refrigerants

Type	ASHRAE number	Chemical name	Chemical formula	ODP	GWP
CFCs	R11	Trichlorofluoro methane	CCl_2F	1	4750
CFCs	R12	Dichlorodifluoro methane	CCl_2F_2	1	10900
HCFCs	R22	Chlorodifluoro methane	$CHClF_2$	0.05	1810
HCFCs	R141b	1,1-Dichloro-1-1fluoroethane	$C_2H_3FCl_2$	0.12	725
HFCs	R407c	R32/125/143a	$23\pm2\%CH_2F_2$ $25\pm2\%C_2HF_5$ $52\pm2\%C_2H_2F_4$	0	1774
HFOs	R1234yf	2,3,3,3-Tetrafluoro propane	$C_3H_2F_4$	0	4
HC	R290	Propane	C_3H_8	0	3.3
HC	R600a	Isobutane	C_4H_{10}	0	3

Table 1.2: Thermodynamic properties of the refrigerants

ASHRAE number	Atmospheric life (year)	Molecular mass	Critical pressure (Kg/mol)	Normal boiling point (bar)	Critical temperature (℃)
R11	45	137.4	4408	23.77	197.96
R12	100	120.9	4136	-29.8	111.97
R22	12	86.5	4990	-40.7	96.14
R141b	9.3	116.9	4250	32	204.2
R407c	15.657	86.2	4634	-43.8	86.05
R1234yf	0.0301	114	——	-29.4	——
R290	12	44.1	4248	-42.1	96.7
R600a	12	58.1	3640	-11.7	134.7

1.3 NANO REFRIGERANT:

A nano-refrigerant is a special class of refrigerant in which the nanoparticles are suspended and immersed in the base refrigerant. The concept of immersing the solid particles into a fluid was first said by Maxwell (1873). He immersed millimetre and micrometre sized particles into the base fluid in order to increase the thermos physical properties of the fluid. With the advent of nanotechnology, Choi (1995) gave a new concept of immersing nanoparticles in the base fluid and called it as nanofluids. The purpose of the development of nanofluids is to increase the heat transfer performance of various heat transfer fluids and lately, this concept has been extended to the refrigerants as well.

The key points of nano refrigerants are:-

1) The use of nano refrigerants will increase in smaller and lighter refrigeration systems.

2) The refrigeration systems using of nanorefrigerants will consume less compressor power it means they will be more energy efficient.

There were three main advantages by using nanoparticle in the refrigerator. Firstly, nanoparticles can increase the solubility between the lubricant and the refrigerant. For example, TiO2 nanoparticles could be used as additives to increase the solubility between mineral oil and hydrofluorocarbon (HFC) refrigerant. The refrigeration systems using the mixture of R134a and mineral oil added with nanoparticles TiO2 gives better performance by returning more lubricant oil back to the compressor and have the similar performance compared to the systems using polyol-ester (POE) and R134a. Secondly, the thermal conductivity and heat transfer characteristics of the refrigerants should be increased which have been sanctioned by a lot of investigations. Boiling heat transfer characteristics of Al2O3 nanoparticles mixed in R22 refrigerant increase the heat transfer characteristic of the refrigerant and the bubble size decrease and move rapidly near the heat transfer surface. Finally, nanoparticles immersed in lubricant should decrease the friction coefficient and wear rate. The friction coefficient of the mineral oil immersed with 0.1 vol.% fullerene nanoparticles decrease compare to raw lubricant which increase the efficiency of the compressor.

The nanoparticles can be appended into the refrigeration system in two different ways. In one way the nanoparticles can be appended to the refrigeration system by first adding them into the lubricant to make a nanoparticles and lubricant mixture. Then the mixtures put into the compressor as the lubricant. In the other way nanoparticles and traditional refrigerant can be dispersed directly to make nano-refrigerant. Both ways improve performance of the refrigerator with the appended nanoparticles. Isobutane (R600a) is more widely used in domestic refrigerator because of its better energy performances.

In fact, many researchers have studied other thermophysical properties as well such as viscosity, specific heat and surface tension. The study of boiling heat transfer involves complexities and these complexities increases due to the addition of nanoparticles in the refrigerant. In past, various results have been done in which the boiling heat transfer performance for nanorefrigerants was found to be higher in comparison to that of the base refrigerant without nanoparticles. Major work has been done using refrigerant nanolubricant pair. The friction coefficient decreases upto 90 % when raw oil is replaced by nano-oil and it has better lubricating characteristics in comparison to the raw oil. Fullerene C60 nano-oil increases the COPs of the compressors and decreases in the compressor shell temperatures which is desirable since a lower compressor shell temperature improve lubricant stability.

Nanofluids as an advanced type of working fluid have attracted due to their capabilities in heat transfer enhancement. Nanofluids are mixtures of ultrafine particles and common working fluids such as water and oil. When a refrigerant is used as the base fluid the suspension is called a nanorefrigerant. By adding the flow boiling of CuO nanoparticles in a mixture of R134a/polyol-easter oil (POE) with 0.5 % weight concentration has no effect on heat transfer enhancement. The R134a/Al2O3 nanorefrigerant with a refrigerator save the energy and increase COP. The concentration of the flow boiling characteristics of the R113/CuO nanorefrigerant inside a horizontal tube at different nanoparticle concentrations increase the heat transfer.

R134a/SiO2 nanorefrigerant having different volume concentrations decrease in convective boiling heat transfer coefficient compared to pure R134a. The R134a/POE mixtures having CuO nanoparticles with different volume fractions increases the heat transfer with increasing volume fractions. Polyolester lubricant of different mass fraction and volume fraction of Al2O3 nanoparticles increases the heat transfer using Al2O3 nanoparticles instead of an R134a/polyolester mixture. The usage of nanorefrigerant in the refrigerant system increases COP and minimizes the length of the capillary tube and it is also cost effective. The potential of R12/TiO2/mineral oil nanorefrigerant enhances the COP of a vapor compression refrigeration system. The usage of nanorefrigerant in the vapor-compression refrigeration system decreases compressor work while increases the COP.

1.4 PROPERTIES OF REFRIGERANTS:

To enable use of smaller compressors and other equipment the refrigerant should have smaller vapor density. To ensure maximum heat absorption during refrigeration, a refrigerant should have high enthalpy of vaporization. Thermal conductivity of the refrigerant should be high for rapidly heat transfer during condensation and evaporation. In order to have large range of isothermal energy transfer, the refrigerant should have critical temperature above the condensing temperature. To have minimum change in entropy during the throttling process, the specific heat should be minimum. The refrigerant used in air conditioning, food preservation etc. should not be toxic in nature as they will come into contact with human beings.

1.4.1 Physical properties of nanorefrigerants

The thermo physical properties and flow properties are important to gauge the effectiveness of a nanofluid or a nanorefrigerant. The thermal conductivity, viscosity, specific heat, latent heat, density and surface tension are some of the most important thermo physical properties of a fluid. Most of the research in past have been done on the thermal conductivity of nanofluids. But lately, the studies based on viscosity have also done. It is important to extend this research to other thermophysical properties since it will give a good idea of the heat transfer performance of nanorefrigerants.

1.4.1.1 Thermal conductivity of nanorefrigerants

The thermal conductivity is one of the most important thermophysical property of a nanorefrigerant because the boiling and convective heat transfer coefficients are a function of the thermal conductivity of the fluid. The thermal conductivity of nanofluids depends on the thermal conductivity values of nanoparticles and base fluid, nanoparticle volume fraction, nanoparticle size, temperature, base fluid material.

1.4.1.2 Viscosity of nanorefrigerants

The addition of nanoparticles to the refrigerant increase in viscosity of the resultant nanorefrigerant. The increment in the thermal conductivity and heat transfer of nanorefrigerant is much higher than the increase in viscosity. The effective viscosity of a nanorefrigerant increases with an increase in particle volume fraction but decreases with an increase in temperature.

1.4.1.3 Pressure Drop in nanorefrigerants

The pressure drop in nanorefrigerants increases because of the addition of nanoparticles. The increase in pressure drop is due to the increase in the effective viscosity of the nanorefrigerant. The specific pressure drop increases with the increase in the particle volume fraction. The pressure drop of the nanorefrigerant increases with increase in particle mass fraction.

1.4.1.4 Other thermophysical properties of nanorefrigerants

There are many other properties like specific heat, density, latent heat and surface tension. The specific heat capacity of nanofluids and nanorefrigerants is thermophysical property which is important because of its uses in energy and exergy performance analysis of the system. The specific heat of nanofluids rely on the type of nanoparticles, volume concentration of nanoparticles, temperature and the type of base fluid. Therefore, the specific heat of nanofluids can either increase or decrease by the addition of nanoparticles.

1.5 ENVIRONMENTAL IMPACT

The halogenated refrigerants have a long history of emission from refrigeration, air conditioning and other uses. The halogenated refrigerants are a family of chemical compounds come from the hydrocarbons (methane and ethane) by replacement of chlorine and fluorine atoms for hydrogen. The emission of chlorine and fluorine atoms present in halogenated refrigerants is liable for the most of environmental effects with serious implications for the future development of the refrigeration based industries.

1.5.1 Ozone Depletion Potential

The first major environmental effect that affect the refrigeration based industries is ODP due to man made chemicals into the atmosphere. Chlorine based refrigerants are enough to reach the stratosphere where the chlorine atoms act as a catalyst to diminish the stratospheric ozone layer (which protects the earth surface from direct UV rays). About 90% of the ozone exists in the stratosphere between 10 and 50 km above the earth surface.

1.5.2 Global Warming Potential

The second major environmental impact is GWP which is because of the absorption of infrared emissions from the earth causing an increase in global earth surface temperature. While so- lar radiation at 5800 K and 1360 W/m2 reaches the earth, more than 30% is reflected back into space and most of the remaining radiation passes through the atmosphere and arrives the surface. This solar radiation heats up the earth radiating energy with a spectral peak in the infrared wave- length range. This infrared radiation cannot pass through the atmosphere because of absorption by GHG including the halogenated refrigerants. As a result, the temperature of atmosphere increases, which is called as the global warming. During the formulation of Kyoto protocol, countries around the world have voluntarily committed to decrease the GHG emissions. HFC refrigerants have large values of atmospheric lifetime and GWP compared to chlorine based refrigerants.

1.6 CHARACTERISTICS OF REFRIGERANTS

Refrigerants are substances that change from the liquid to the gaseous state to reduce the temperature of a devices. This chemical process is used over and over again in refrigerators, air conditioners and other machines to maintain the items inside cool. Different refrigerants are used depending on the location, the type of machine and the application of items that are refrigerated.

1.6.1 Boiling Point

A refrigerant should have a boiling point in a particular range that fits the machine in which it is used. A refrigerant with a lower boiling point tends to have a better ability to cool. Refrigerants with higher boiling points is more efficient and do work good in a smaller machine. Most refrigerants have a boiling point between - 27.4 and - 49 degrees Fahrenheit, though many have a boiling point as high as 48.2 degrees Fahrenheit.

1.6.2 Toxicity

A refrigerant is classified as a Class A refrigerant if there is no toxicity identified in concentrations less than 400 parts per million. If there is toxicity identified in this small amount, the substance is a Class B refrigerant. Class 1 refrigerants are completely nonflammable, Class 2 types are moderately flammable and Class 3 substances are highly flammable. A good refriger- ant has the proper combination of safety and functionality.

1.6.3 Stability

Refrigerants must be stable substances that do not decompose under the pressures and temperatures of the refrigerator system. A less stable substance might dissolve the plastics used in the motor and seals of the system. The refrigerant should also not react chemically with the lubricants and other substances used in the refrigerator. Originally, chlorofluorocarbons (CFCs) were used as refrigerants until it was decided that they were unstable when they came into con- tact with the ozone particles in the upper atmosphere.

1.6.4 Odor

A good refrigerant has no odor when it is in a low concentration so that the devices does not have a chemical smell at all times. This refrigerant also has a different odor at higher concentrations so that when a device has chemical leaks, they can be instantly identified.

1.6.5 Pressure

Generally all the new refrigerants operate at a higher pressure than the refrigerants they replace. In many cases the pressure can be substantially higher, which means that the refrigerant can be used only in equipment designed to use it.

1.6.6 Material compatibility

The primary safety concern is with wearing of materials, such as motor insulation, which can lead to electrical shorts, and seals, which can result in leaks.

1.6.7 Flammability

Leakage of a flammable refrigerant could result in explosions. Some new refrigerants are zeotropes which can change composition under many leakage scenarios.

II. LITERATURE REVIEW

1. In June 2017, Ms. Vidya N. Lakhorkar, Mr. Sulas G. Borkar [1] worked on Performance Evaluation of Domestic Refrigerator Using Eco-Friendly Refrigerant: A Review. This paper is a review of one of the ecofriendly refrigerant used in the domestic refrigerator. The performance of the refrigerator was studied using R134a refrigerant and mixture of propane R290 and isobutene R600a (50/50). Then this increases performance because of mixture of propane R290 and isobutene R600a (50/50) was compared with performance of refrigerator working with R134a and percentage of increment was calculated on the basis of COP, refrigerating effect, power required to run the compressor, etc. It can be concluded that hydrocarbon refrigerant gives good results as compared to the existing refrigerant R134a. The hydrocarbon refrigerant have low value of GWP (Global warming potential) as compared to the R134a. So it does not harm the ozone layer and hydrocarbon can be consider as ecofriendly refrigerant. It reduces energy consumption by 11.1+% compare to R134a. It increases COP up to 3.25-3.6%. It also reduces Pull down time 11.6 compare to R134a%.

2. In 2017, Tejaswi Saran Pilla, Pranay Kumar Goud Sunkari et al.[2] worked on Experimental evaluation Mechanical performance of the compressor with mixed refrigerants R-290 and R-600a. Hence, in the present work, two refrigerants are chosen (R-290 and R-600a) to evaluate the mechanical performance of compressor of domestic refrigerators. The present work aims at investigation of mechanical performance of compressor with mixed refrigerants (R-290 and R-600a). The boiling point of the each of the refrigerant is different and hence the specific volume occupied by each is different. This in turn affects the work input required. Hence, the present work is aimed at evaluating the compressor performance with mixed refrigerants. The present work concludes that 60% of R290 and 40% of R600a composition has better performance in all parameters such as mass flow rate, power consumption, experimental COP, Carnot COP and discharge temperature. Small compressors can be use instead of usual one to obtain equal performances by using 10% of R290 and 90% of R600a composition. Because it also has better performance parameters along with 60% of R290 and 40% of R600a composition and also it consumes low power hence energy will save. It has highest Carnot COP. It means almost equals to ideal cycle for some extent.

3. In October 2015, Teboho Ramathe, Zhongjie Huan and Aggrey Mwesigye [3] worked on Experimental Study on the Thermal Performance of R600a, R290 and R600a/R290 Mixtures in a Retrofit R134a Refrigeration System. In this paper, the experimental thermodynamic performance evaluation of the hydrocarbons R600a, R290 and

their mixtures used in a vapour compression refrigeration system that utilizes R134a as a working fluid was carried out. Firstly, a theoretical analysis was developed to evaluate the feasibility of the retrofit by employing the vapour compression refrigeration cycle. The evaporation temperatures were ranging from -25 °C to 3 °Cand the condensation temperatures ranging from 25 °C to 65 °Cwith superheating and subcooling degrees constant at 5 °C. The thermodynamic and thermophysical properties were obtained using REFPROP soft- ware. Lastly, based on the results obtained from the theoretical analysis, the experimental comparison of the refrigeration cycle performance was conducted using a refrigeration system designed for R l34a. The results show that both pure R600a and R290 cannot be recommended as drop-in substitutes for R134a due to their significant differences in thermophysical properties. A mixture of R600alR290 50%/50% composition was found to be the most appropriate alternative refrigerant for the Rl34a system retrofit with a comparative thermal performance. Hydrocarbons perform favourably in comparison with halo- carbon refrigerants.

4. In June 2015, DEEPAK PALIWAL, S.P.S.RAJPUT [4] worked on EXPERIMENTAL ANALYSIS OF HYDROCARBON MIXTURES AS THE NEW REFRIGERANT IN DOMESTIC REFRIGERATION SYSTEM. As and when an existing system of R134a has to be recharged it is suggested to retrofit the system with new/natural and alternative refrigerants. This investigation focuses on mixture ratio of pure hydrocarbon R290 and R600a uses in 200 liter domestic refrigeration system by certain changes in con- denser and capillary. The outcome of this work is 80g mixture of R600a/R290 (60/40 by wt%) give better performance than 80g mixture of R600a/R290 (70/30 by wt%). COP of R600a/R290 (60/40 by wt%) mixture is higher in the range 22%-26.3% than mixture R600a/R290 (70/30 by wt%) for capillary of 3.5m length and 0.036 inches diameter. During the experiments it is found that 0.036 inches dia. capillary is more suitable as expansion device than 0.031 inches dia. capillary at all length . It is also find out that by increasing the length of capillary in the system hydrocarbon mixture give better results. Refrigerating effect of R600a/R290 (60/40 by wt%) mixture was higher in the range 26.8%-37% in lower evaporating temp. and higher 22.8% -48.8% in higher evaporating temp. than R600a/R290 (70/30 by wt %) for 3.5m length capillary 0.031 inches dia. and 0.036 inches diameter. Energy Consumption of R600a/R290 (60/40 by wt %) mixture was higher in the range 19.6% - 30.7% than R600a/R290 (70/30 by wt %) mixture for capillary 3.5 M length and .036 inches diameter.

5. In May 2014, Mao-Gang He, Xin-Zhou Song et al. [5] worked on Application of Natural Refrigerant Propane and Propane/Isobutane in Large Capacity Chest Freezer. In this paper, some researches have been conducted on natural refrigerant propane (R290) and its mixtures substituting for 1,1,1,2-Tetrafluoroethane (R134a) used in a large-capacity chest freezer (BD-625). To examine the application possibilities of R290 and its mixtures to the large-capacity freezer, their thermodynamic and refrigeration performances from both theoretical analysis and experimental test have been done. The theoretical analysis shows that R290 is higher by 87.7% and 54.2% than R134a in mass and volumetric refrigerating capacity respectively. Propane/Isobutene (R290/R600a, 90/10 wt%) is higher by 48.3% and 2.4% than R134a in volumetric refrigerating capacity and COP respectively. So R290 and its mixtures (R290/R600a) can meet the requirements of large-capacity refrigeration and energy conservation as the alternatives of R134a. The experimental test shows that the power consumption of the experimental freezer charged with R290 is lower by 26.7% than that of R134a. The ratio of R290/R600a is 93.75/6.25Wt% when it is used in the freezer and the corresponding power consumption is lower by 27.5% than that of R134a. The charging amount of R290 is less than that of R134a, which is in line with the safety standards, So R290 can be used in the large capacity chest freezer. The COP of R290 is lower by about 4.7% than that of R600a from the theoretical calculation. The experimental test shows the power consumption of the ratio R290/R600a is 1.71 kWh/24h, which is lower by 1.2% than that of R290 in the tested freezer.

6. In July 2013, Mehdi Rasti, SeyedFoad Aghamiri et al. [6] worked on Energy efficiency enhancement of a domestic refrigerator using R436A and R600a as alternative refrigerants to R134a. This paper is devoted to feasibility study of substitution of two hydrocarbon refrigerants instead of R134a in a domestic refrigerator. Experiments are designed on a refrigerator manufactured for 105 g R134a charge. The effect of parameters including refrigerant

type, refrigerant charge and compressor type are investigated. This research is conducted using R436A (mixture of 46% iso-butane and 54% propane) and R600a (pure iso-butane) as hydrocarbon refrigerants, HFC type compressor (designed for R134a) and HC type compressor (designed for R600a). It can be concluded that for HFC type compressor, the optimum refrigerant charges are 60 g and 55 g for R436A and R600a. Moreover, for this type of compressor, the energy consumption of R436A and R600a at the optimum charges is reduced about 14% and 7% in comparison to R134a. On the other hand, when using HC type compressor, the optimum refrigerant charges for R436A and R600a are both 50 g, and the energy consumption of R436A and R600a at the optimum charges are reduced about 14.6% and 18.7%, respectively.

7. In September 2008, M. Mohanraj, S. Jayaraj et al. [7] worked on Experimental investigation of R290/R600a mixture as an alternative to R134a in a domestic refrigerator. In the present work, an experimental investigation has been made with hydrocarbon refrigerant mixture (composed of R290 and R600a in the ratio of 45.2:54.8 by weight) as an alternative to R134a in a 200 l single evaporator domestic refrigerator. Continuous running tests were performed under different ambient temperatures (24, 28, 32, 38 and 43 âŮęC), while cycling running (ON/OFF) tests were carried out only at 32 C ambient temperature. It can be concluded that the hydrocarbon mixture has lower values of energy consumption; pull down time and ON time ratio by about 11.1%, 11.6% and 13.2%, respectively, with 3.25 to 3.6% higher coefficient of performance (COP). The discharge temperature of hydrocarbon mixture was found to be 8.5 to 13.4 K lower than that of R134a. Hence, the life of the compressor can be improved. Temperature variation in the evaporator is found to be within 3 K. The miscibility of HCM with POE was found to be good. 8. HCM also reduce the indirect global warming due to its higher energy efficiency. The overall performance has proved that the above hydrocarbon refrigerant mixture could be the best long term alternative to phase out R134a.

8. In January 2006, M. Fatouh, M. El Kafafy [8] worked on Assessment of propane or commercial butane mixtures as possible alternatives to R134a in domestic refrigerators. The possibility of using hydrocarbon mixtures as working fluids to replace R134a in domestic refrigerators has been evaluated through a simulation analysis in the present work. The performance characteristics of domestic refrigerators were predicted over a wide range of evaporation temperatures (-35°Cto -10 °C) and condensation temperatures (40°Cto 60°C) for various working fluids such as R134a, propane, commercial butane and propane/iso- butane/n-butane mixtures with various propane mass fractions. The performance characteristics of the considered domestic refrigerator were identified by the coefficient of performance (COP), volumetric cooling capacity, cooling capacity, condenser capacity, input power to compressor, discharge temperature, pressure ratio and refrigerant mass flow rate. It can be concluded that pure propane could not be used as a drop in replacement for R134a in domestic refrigerators because of its high operating pressures and low COP. The coefficient of performance of the domestic refrigerator using a ternary hydrocarbon mixture with propane mass fractions from 0.5 to 0.7 is higher than that of R134a. Comparison among the considered working fluids confirmed that the average refrigerant mass flow rate of the propane/commercial butane mixture is 50% lower than that of R134a. The pressure ratio of the hydrocarbon mixture with 50%, 60% and 70% propane is lower than that of R134a by about 6.3%, 11.1% and 15.3%, respectively. Finally, the reported results confirmed that the propane/iso-butane/n-butane mixture with 60% propane is the best drop in replacement for R134a in domestic refrigerators under normal, subtropical and tropical operating conditions.

9. In March 2004, Somchai Wongwises, Nares Chimres [9] worked on Experimental study of hydrocarbon mixtures to replace HFC-134a in a domestic refrigerator. This work presents an experimental study on the application of hydrocarbon mixtures to replace HFC- 134a in a domestic refrigerator. The hydrocarbons investigated are propane (R290), butane (R600) and isobutane (R600a). A refrigerator designed to work with HFC-134a with a gross capacity of 239 l is used in the experiment. The consumed energy, compressor power and refrigerant temperature and pressure at the inlet and outlet of the compressor are recorded and analysed as well as the distributions of temperature at various positions in the refrigerator. The refrigerant mixtures used are divided into

three groups: the mixture of three hydrocarbons, the mixture of two hydrocarbons and the mixture of two hydrocarbons and HFC-134a. The experiments are conducted with the refrigerants under the same no load condition at a surrounding temperature of 25 °C. It can be concluded that propane/butane 60%/40% is the most appropriate alternative refrigerant to HFC-134a. The distributions of temperature in the frozen food storage compartment and in the fresh food storage compartment in the refrigerator, energy consumed, compressor power, refrigerant temperature and pressure at the inlet and outlet of the compressor were continuously recorded. The best alternative mixture of HFC-134a in each group was selected and proposed based on the above information.

10. In November 2001, Y.S. Lee, C.C. Su [10] worked on Experimental studies of isobutane (R600a) as the refrigerant in domestic refrigeration system. This paper presents an experimental study on the performance of a domestic vapor-compression refrigeration system with isobutane (R600a) as the refrigerant. The input power of the compressor varied be- tween 230 and 300 W, while the amount of the charged refrigerant was about 150 g. The expansion and heat transfer components of the system were capillary tubes and plate heat exchangers, respectively. The refrigeration temperatures were set at about 4 and -10°C to simulate the situations of the cold storage and the freezing applications. Both normal and extreme conditions were investigated in this work. The COPs of the domestic vapor- compression refrigeration system under study are between 1.2 and 4.5 in the cold storage application and between 0.8 and 3.5 in the freezing application. For the inlet temperature of the brine of 4 and -10°C, the COPs are greater than 3.5 and 2.5 respectively if proper sizes of capillary tubes are chosen. The system with two capillary tubes in parallel per- forms better in the cold storage and air conditioning applications, while that with a single tube is suitable in the freezing application.

11. In March 2017, T. Vasudevan, N. Prakash et al. [11] worked on Experimental Investigation on Performance of Refrigerant System using Titanium Dioxide. This project shows an experimental investigation of constant mass of refrigerant gases R-134a and R-600a (70g) enhanced with varied TiO2 nanoparticles. Nanoparticles are converted into nanofluids using distilled water as a base fluid. By adding nanofluid with refrigerants it improves thermophysical properties and heat transfer characteristics of refrigerant and the con- centration used for preparing nanofluids are (2 g/L, 2.5 g/L). Then Performance test are maintained at steady state includes power consumption, compressor power input, cooling capacity and coefficient of performance. Analysis was based on temperature and pressure readings obtained from appropriate gauges and power consumption is recorded by energy meter which are attached to the kid. It has been noticed that the mechanical properties of finding C.O.P in refrigeration system is achieved using two refrigerants R-134a and R- 600a with nano fluid. The comparison itself shows that common water has less efficiency (for R- 134a it is 0.4888 and for R-600a it is 0.402) and it consume more power (for R-134a it is 70 mins and for R-600a it is 91 mins) but while using nanofluid the efficiency is increased (R-134a it is 0.5546 and for R-600a it is 0.584) and it consume less power R-134a it is 62 mins and for R-600a it is 59.25 mins).

12. In April 2017, V.K. Dongare, Jyoti Kadam et al. [12] worked on ENHANCEMENT OF VAPOUR COMPRESSION REFRIGERATION SYSTEM USING NANOFLUIDS. In past five years, nano-refrigerant has become the input for large number of experimental and vapours compression systems because of shortage of energy and environmental considerations. The conventional refrigerants have major role in global warming and depletion of the ozone layer. By adding nanoparticles with refrigerants the coefficient of performance, heat transfer rate and thermal conductivity will increased. Because of that power consumption rate will be reduced. This paper compares coefficient of performance of refrigeration system with nanorefrigerants and without nanorefrigerants such as R134a, Mo49 and blend of R290 and R600a. The COP of refrigeration system with nanoparticles is more than COP of refrigeration system without nanoparticles. The COP of refrigeration system with nanoparticles is increased by 4-5%. COP of CuO nanoparticles is more than Cop of Al2O3 nanoparticles with refrigerants. COP also differs with types of refrigerants R134a, R290 & R600a. The heat transfer rate and thermal conductivity of system will increased by using nanorefrigerants.

13. In December 2016, M.S.Bandgar, R. N. Kare et al. [13] worked on VCR SYSTEM USING R-600a/ POE OIL/MINERAL OIL/NANO-SiO2 AS WORKING FLUID: AN EXPER- IMENTAL INVESTIGATION. The aim of this work is to evaluate the performance of Vapour Compression Refrigeration System using SiO2 nano particles mixed with Poly- olester(POE) oil / Mineral oil (MO) as Nano lubricant and R-600a as a refrigerant. This paper investigates which type of lubricant oil works better with SiO2 nanoparticles in the field of refrigeration. POE Oil / Mineral Oil are mixed with Silica Nano particles by ultrasonic sonication and stirring process to prepare the Nano lubricants. These Nano lubricants were used in the compressor of refrigeration system instead of RL68H oil/SUNISO 3GS oil. An investigation was done on the compatibility of POE/Mineral oil mixed with Silica (SiO2) Nano powder (at a concentration of 0.5%, 1% and 1.5% by mass fraction) as Nano lubricant. The replacement of Polyol-ester lubricant by the mineral lubricant mixed with SiO2 reduces power consumption. It gives better results at mass fraction of 0.5% for all combinations of Nano-oils. It was found that the time required reducing the temper- ature of water though 10 °Cis less and the power consumption reduces by 12.02% when POE oil is replaced by a mixture of (MO 0.5% Silica). It has been observed that C.O.P. is increased by 11.66% when POE is replaced by a Nano lubricant (mineral oil 0.5% of SiO2). The freezing capacity is better at 0.5% of SiO2 and it is highest for system using POE oil mixed with 0.5% SiO2 as lubricant. Thus the use of above Nano lubricants in refrigeration system is favorable.

14. In 2015, Omer A. Alawi, Nor Azwadi Che Sidik et al. [14] worked on Nanorefrigerant effects in heat transfer performance and energy consumption reduction: A review. The heat transfer performance and energy consumption of various thermal devices may be augmented by active and passive techniques. One of the passive techniques is the addition of nanoparticles to the common heat transfer fluids so that the thermal transport properties of the prepared suspension (called nanofluid) will be enhanced as compared to the base fluid. Nanorefrigerants are a special type of nanofluids which are mixtures of nanoparticles and refrigerants and have a broad range of applications in diverse fields for instance refrigeration systems, air conditioning systems, and heat exchangers. This review is performed in order to clarify the effect of nanorefrigerant properties on heat transfer and pressure drop compared to pure refrigerant. Moreover, studies related to the thermophysical properties, and applications of nanorefrigerants to some specific areas such as domestic refrigerators, heat pipes and air conditioners are also summarized. Energy consumption can be reduced by using nanorefrigerants. It is reported that the freezing speed and COP in cooling de- vices are increased by adding nanoparticles to the refrigerants. The heat transfer rate and pressure drop increase with increasing nanoparticle proportion. The heat transfer rate in- creases with a decreasing nanoparticle dimension while the pressure drop decreases with a decreasing nanoparticle dimension. The lubricant type has the potential to enhance the heat transfer rate.

15. In April 2015, A.Senthilkumar, R.Praveen [15] worked on PERFORMANCE ANALYSIS OF A DOMESTIC REFRIGERATOR USING CUO âĂŞR600A NANO REFRIGERANT AS WORKING FLUID. The application of nano refrigerants in refrigeration system is considered to be a potential way to improve the energy efficiency and to make the use of environment-friendly refrigerants. In this paper it is reported a method that uses natural gas to enhance the energy efficiency of refrigeration retorting method employing CuO - R600a as alternate refrigerants. Thus reliability and performance of nano refrigerant in the working fluid have been investigated experimentally. A new nano refrigerant is employed in the domestic refrigerator. The performances of the nano refrigerant, such as the cooling capacity, energy efficiency ratio were determined. Combined with refrigerator using pure R600a as working fluids. 0.1 & 0.5g/L concentrations of CuO - R600a can save 11.83% and 17.88% energy consumption respectively and the freezing velocity of CuO - R600a was more quickly than the pure R600a system. So the above works have concluded that CuO - R600a can improve the performance of the domestic refrigerator.

16. In April 2014, S. A. Fadhilah, R. S. Marhamah et al. [16] worked on Copper Oxide Nanoparticles for Advanced Refrigerant Thermophysical Properties: Mathematical Modeling. Nanorefrigerant which is one kind

of nanofluids has been introduced as a superior properties refrigerant that increased the heat transfer rate in the refrigeration system. Many types of materials could be used as the nanoparticles to be suspended into the conventional refrigerants. In this study, the effect of the suspended copper oxide (CuO) nanoparticles into the 1,1,1,2-tetrafluoroethane, R-134a is investigated by using mathematical modeling. The investigation includes the thermal conductivity, dynamic viscosity, and heat transfer rate of the nanorefrigerant in a tube of evaporator. The thermal conductivity of refrigerant-134a is 0.0139 W/mK at temperature of 26°C. Additional 1% volume fraction has increased the thermal conductivity in range of 3.53âĂŞ8.38% up to 5% volume fraction. The viscosity of nanorefrigerant is also showing great percentage of enhancement which is about 44.45% once compared to the conventional refrigerant with only 1% of nanoparticles volume fraction. The heat transfer rate of a tube of nanorefrigerant with 5% vol. fraction is about 1% enhancement.

17. In April 2013, R. Reji Kumar ,K. Sridhar et al.[17] worked on Heat transfer enhancement in domestic refrigerator using R600a/mineral oil/nano-Al2O3 as working fluid. Aluminium oxide nanofluid is used for enhancing the heat transfer capacity of the refrigerant in the refrigeration System. In this experiment heat transfer enhancement was investigated numerically on the surface of a refrigerator by using Al2O3 nano-refrigerants, where nanofluids could be a significant factor in maintaining the surface temperature within a required range. The addition of nanoparticles to the refrigerant results in improvements in the thermophysical properties and heat transfer characteristics of the refrigerant, thereby improving the performance of the refrigeration system. Stable nanolubricant has been prepared for the study. The R600a refrigerant and mineral oil mixture with nanoparticles worked normally. Freezing capacity of the refrigeration system is higher with mineral oil + alumina nanoparticles oil mixture compared the system with POE oil. The power consumption of the compressor reduces by 11.5% when the nanolubricant is used instead of conventional POE oil. The coefficient of performance of the refrigeration system also increases by 19.6% when the conventional POE oil is replaced with nanorefrigerant.

18. In August 2011, Shengshan Bi, Kai Guo et al. [18] worked on Energy Conversion and Management. In this work, an experimental work was investigated on the nano-refrigerant. TiO2-R600a nano-refrigerants were used in a domestic refrigerator without any system re- construction. The refrigerator performance was then investigated using energy consumption test and freeze capacity test. It can be concluded that TiO2-R600a nano-refrigerants work normally and safely in the refrigerator. Compared with refrigerator using pure R600a as working fluids, 0.1 and 0.5 g/L concentrations of TiO2-R600a can save 5.94% and 9.60% energy consumption respectively and the freezing velocity of nanorefrigerant system was more quickly than the pure R600a system. above works have demonstrated that nanoparticles can improve the performance of the domestic refrigerator.

III CONCLUSION

The present study gives a comprehensive review of the various studies related to use of nanorefrigerants in refrigeration systems. Based on the results of different studies relevant to nanorefrigerants the following points can be drawn:

- The use of nanorefrigerants as refrigerants are not just good for the environment but also it can reduce the energy consumption and offer proper refrigerants for the performance of domestic refrigerator.
- The convenient thermodynamic and thermo-physical properties of nanorefrigerants assure that the performance of the domestic refrigerator is comparable to the traditional refrigerants.
- Nanorefrigerants offer interesting refrigerant as alternatives for conventional ones from the standpoint of energy efficiency, cooling time and compressor's discharge-temperatures.

IV ACKNOWLEDGEMENTS

I would like to thank Ass. Professor Hussain Pipwala for his invaluable guidance and patience during this work. He took great efforts in providing good guidance and was enthusiastic about my work. He gave so many advices on this work, expressing the idea. It was a pleasure working with him and more importantly, learning from him. I owe him a great debt of gratitude. Many sincere thanks to Head of Department Dr. S.J.Thanki and Principal Dr. R.G.Kapadia for the support in this work. I express my deep and sincere sense of gratitude to all the faculty members and institute staff of Mechanical Engineering at Shri S'ad Vidya Mandal Institute of Technology.

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