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A Review Paper on Comparative Study of Household-Refrigerator with Alternative Low Global Warming Potential Refrigerants

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Abstract : *This paper deals simulation study to investigation for the exploring of environmentally friendly alternative refrigerants for the R-12,R-22 and R134a for low Global Warming Potential (GWP), negligible Ozone Depletion Potential (ODP) and a better Coefficient of Performance (COP).The performance characteristics of household refrigerators were predicted using steady-state model under refrigeration capacity (200 W), constant evaporation temperature (-10 °C) and condensation temperature (46 °C) for various working fluids such as R-12,R-22 and R-134a this study was carried out by comparing parameters such as coefficient of performance, compressor power, volumetric cooling capacity, discharge temperature and mass flow rate of refrigerant*

Keywords: *COP, R-12, R-22 and R-134a, GWP, ODP, Household Refrigerator.*

I. INTRODUCTION

Refrigeration is defined as the process of achieving and maintaining a temperature below that of surrounding, the aim being to cool some product or space to the required temperature. One of the most important applications of refrigeration has been preservation of perishable food products by storing them at low temperatures. Refrigeration systems are also use for providing thermal comfort to human beings by means of air conditioning[6].

For the past half century, chlorofluorocarbons (cfcs) have been used extensively in the field of refrigeration due to their favorable characteristics. In particular, CFC12 has been approximately used for small refrigeration units including domestic refrigerator/freezer. Since the advent Montreal protocol as the CFC12 has high ODP and GWP the refrigeration industry has been trying to find out best substitutes for ozone depleting substances. For a past decade, HFC 134a has been used to replace CFC12 using refrigerator and automobile air conditioners. HFC 134a has such favorable charactristics.as zero ozone depletion potential, non-flammability, stability, similar vapors pressure to that of CFC12 show that the performance of HFC 134a in refrigerator in with proper compressor and lubricant is quite comparable to that of CFC12 similarly for performance of CFC12 and HCFC22 in refrigerator with proper compressor and lubricant is quite comparable[1].

Therefore we are doing comparative study of environment friendly refrigerants in domestic refrigerators. A domestic refrigerator works upon vapor compression refrigeration cycle. Vapor compression cycles are basically divided into four basic process:

A. Isentropic compression process
B. Isobaric heat rejection process
C. Isentropic expansion and
D. Isobaric and isothermal heat extraction.

A. Isentropic compression process:-The Isentropic compression is shown by the line 1-2.Since the vapour is dry and saturated at the start of compression it becomes superheated at the end of compression as given by point 2.

B. Isobaric heat rejection process:-The Isobaric heat rejection process is shown by the line 2-3.The process of condensation which takes place at constant pressure line 2-3

C. Isenthalpic expansion process:-The vapour now reduced to saturated liquid is throttle through the expansion valve and line as shown by 3-4

D. Isobaric Process:-The dry saturated vapour is drawn by compressor from evaporator at lower pressure P_4 and then it vapour is compressed isentropic ally to the pressure P_2.

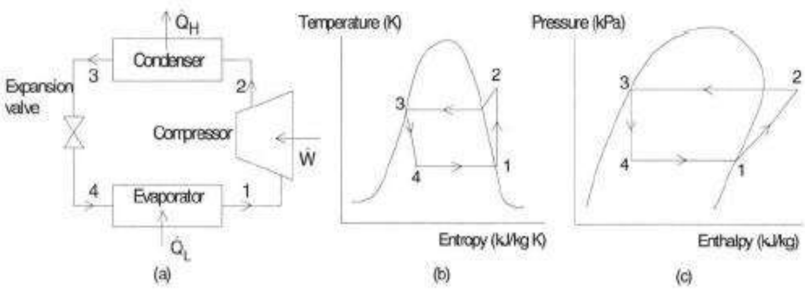

Fig. Vapour compression cycle on P-h Diagram

The coefficient of performance is expressed as COP which defined as

$$COP = \frac{\text{Refrigerating Effect}}{\text{Compressor Work}} = \frac{(h_1 - h3)}{(h2 - h1)} \quad \ldots..(1)$$

The actual COP is lower than the theoretical COP and is calculated by performing the experiment in the laboratory[7].

Types of refrigerants used in household refrigerator

Refrigerants are working fluids in refrigeration and air-conditioning systems. The refrigerant absorbs the heat from the space to be cooled through the evaporator and then reject it to the outside through the condenser. The refrigerants used and the alternative refrigerants must meet many requirements, the following features are considered as major standards in the selection of proper refrigerants such as environmental safety ,Chemical stability, Satisfactory thermal and physical properties, high latent heat of vaporization, Low cost, no corrosiveness, non-toxicity, Short atmospheric lifetimes, non-explosive, and Non-flammable .Unfortunately, there are no long-term refrigerants have all of these properties that fully meet these requirements, but at least both Eco-friendly and energy-efficient. There are different types of refrigerants which are described as following[2].

R-11trichloromonoflouromethane (CCL3F)

The R-11 is a synthetic chemical product which can be used as a refrigerant. It is stable, non-flammable and non-toxic. It is considered to be a low pressure refrigerant. It has a low side pressure of 0.202 bar at-15 C and high pressure of 1.2606 bars at 30 C. The latent heat at-15 C is 195 KJ/kg. The boiling point at atmospheric pressure is 23.77 C. due to its low operating pressures; this refrigerant is exclusive used in large centrifugal compressor of 200TR and above. The leaks may be detected by using a soap solution, a halide torch or by using an electronic detector.

R-12 dichlorodifluoromethane (CCL2F2)

The R-12 is a very popular refrigerant. It is a colorless, almost odorless liquid with boiling point of -29^{0}C at atmospheric pressure. It is non-toxic, non-corrosive, non-irritating and non-flammable. It has a relatively low latent heat value which is an advantage in small refrigeration machines. R-12 has a pressure of 0.82 bars at -15^{0}C and a pressure of 6.4 bars at 30^{0}c. The latent heat of R-12 at -15^{0}c is 159KJ/kg.

R-134a tetrafloroethane (C2H2F4)

The preferred replacements of R-12 can be the HFC refrigerants R-134a. This has a boiling point of -26.2^{0}C which bears reasonable comparison with the boiling point of R-12 (-29.8^{0}C). R-134 is a not a drop in replacement of R-12 because the refrigerating effect is slightly different. It does not seem to be compatible with conventional lubricants or more winding insulation. It gives higher benefits thenR-12 in using in conventional refrigerators where reasonable condensing temperature is specified. This would appear to be non-flammable and nontoxic substitute for R-12 at extreme pressure ratios.

Propane + Isobutene (R290/R600a-LPG)

It is an azeotropic mixture of propane (R290) &isobutene (R600a). It has Property very similar to R12 & R 134 which is commonly used refrigerant now days. This blend of hydrocarbons is used in most of the AC of European cars. It contains 60% propane+40%iso butane. It is named as mint gas because it has cooling property like mint. Moreover it has zero ozone depletion potential and a reliable global warming potential (the two property due to which we need to replace the CFC's).

R410A-difluoromethane/pentafluromethane (CH2F2/CHF2CF3)

R410A is azeotropic HFC blend of R125 and R32. In Australia R410A is a popular product for commercial and residential air conditioning systems as an alternative to R22. R410A exhibits higher pressures than R22 so is used in new equipment rather than as a retrofit gas.

R22- chlorodifluromethane (HCFC-22)

R22 is a single component HCFC refrigerant that has historically been used for air conditioning, medium temperature and low temperature refrigeration. R22 causes ozone depletion and as a result is subject to Legislation that is phasing down its use in Australia.

Hydrocarbons (HC)

Natural refrigerants refer to all non-synthetic natural materials. It can be drawn directly from the environment, including hydrocarbons (HC) propane (R290) and isobutene (R600a).Natural refrigerants are low global warming potential because they can easily be absorbed by nature. HCs have good thermodynamic properties and heat transfer performance, zero ODP and GWP near the unit, but are dangerous because of their flammability. Flammable gasses are common in many technical applications and do not cause many problems when observing simple precautions. Another area where propane could be a substitute for R-12 in the future refrigerators and freezers[2].

Table1: Properties of Alternative Refrigerants

Refrigerants	Critical Temperature	Boiling Point(at 1 ATM)	Molecular Weight	GWP	ODP
R22	96.2 °C	-40.8 ^{0}C	86.5	1700	0.55
R134a	101.2°C	-26.1°C	102.3	1300	0
R600a	105.5°C	-31.7°C	51	3	0

II. Literature Review

A Baskaran, P.koshy Mathews studied the comparative analysis of Environment Friendly Alternatives to R12 and R134a in Domestic Refrigerator. They conclude that the pressure ratio of refrigerant mixture 1 and 2 substituted for R12 and R134a was 10.61% higher and 8.07% lower than that of R12 and R134a.and show that refrigerating effect increases with increasing evaporation temperature while compressor power decreases with increasing temperature of evaporator[1].

Kamel Sigar Hmood, Horatiu Pop, Valentin Apostol, Ahmed Qasim Ahmed,Refrigerants Retrofit as Alternative for R12 and R134a in Household Refrigerators, In this theoretical study, appropriate environmental solutions in one than refrigeration applications (household refrigerator) in Iraq were investigated. Household refrigerator is one of a Vapor compression refrigeration systems which used the refrigerants as working fluids[2].

Rajanikant Y. Mahajan, Sanjaykumar A. Borikar studied the "Performance Evaluation of Domestic Refrigerator Using Hc-12a Refrigerant as an Alternative Refrigerant to R12 And R134a" 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[3].

B.Tashtoush, M.Tahat, M.A.Shudeifat they conducted study on new refrigerant mixture to replace R12 in domestic refrigerators, it was observed that the R290/R600a (30/70), R290/R600 (40/60), R290/R600a (50/50), R290/R600 (60/40) and R290/R600 (70/30) refrigerant blend could be a viable alternative HFC134. From the experimental study it has been observed that the refrigerant capacity and COP of selected refrigerants increases with increasing evaporator temperature and decrease with constant condensing temperature[4].

W.chen conducted a comparative study on performance and environmental characteristics of R404A and R22 residential air conditioners.by comparing R12 and R410a they should be helpful to develop air conditioners with higher operation efficiency. Since R410a has better transport properties and higher working pressure, the refrigerant pressure loss and its impact on the system performance is relatively smaller[5].

Shrikant Dhavale, Dr. Manish Deshmukh focuses on an experimental study of hydrocarbon blend of isobutene R600a and propane R290 as an environmental friendly refrigerator with zero ozone depletion potential and very low global warming potential, to replace conventional refrigerators tetrafloroethene R134a in a domestic refrigerator[6].

M.Abuzar Qureshi, Shikha Bhatt, studied the Comparative Analysis of Cop Using R134a & R600a Refrigerant in Domestic Refrigerator at Steady State Condition, in this paper an experimental work is calculated by comparing the coefficient of performance using refrigerant R-600a (Isobutane) and R-134 (tetrafluoraethane) at steady state condition[7].

Ajoy Bhargav, Nitin Jaiswal studied the Comparative Analysis of R290/R600a with commonly used refrigerant, In the above study comparison of mint gas is done with R-12 and R-134 for in domestic refrigerators. Mint gas is providing more COP then ordinary refrigerants another advantage of this refrigerant was that it does not react with compressor oil[8].

III. Environmental Impact

Halogenated refrigerants are considered for refrigeration, air conditioning, and other long-term uses. Halogenated refrigerants are a family of chemical compounds derived from hydrocarbons (methane and ethane) by replacing chlorine and hydrogen fluoride atoms. Chlorine and fluorine emissions in halogenated refrigerants are responsible for major environmental impacts that have serious implications for the future development of refrigeration-based industries[2].

All refrigerants which are using in domestic and industrial purposes are affected on environment directly or indirectly, so depending upon environmental issues we need to find Eco-friendly refrigerants. So first we are going to study the environment how these refrigerants are affected as follows,

- Global Warming
- Ozone depletion Potential

Global Warming

The global warming effect is the phenomenon of increase in earth's surface temperature because of the absorption of long wave radiation by certain vapors and greenhouse gases. The CFCs, HCFCs and HFCs are all greenhouse gases. Because of their molecular structure, they all have strong absorption featuares in the so-called window region of the infrared. The window region is the wavelength region from about 7 to 13μm, where absorption by the primary absorbers CO2 and H2O is weak (Wobbles 1994). Global Warming Potential (GWP) has been scaled with reference to carbon dioxide, which has GWP = 1.0.

Ozone Depletion Potential

Chlorofluorocarbons, which are a family of chemical compounds derived from simple hydrocarbons (methane, ethane, etc.) by substitution atoms with halons (chlorine and fluorine), have been known and characterized since the 1890s. In 1928 Thomas Midgley projected these simple hydrocarbon derivatives as working fluids in refrigeration equipment. The CFCs possess most of the desirable characteristics, such as chemical stability, high thermodynamic efficiency, non-toxicity, non-flammability, etc. However the ozone depleting Effect of CFCs is of great concern because of the harmful ultra violet radiation that might otherwise reach the surface of the earth (Rowland and Molina 1974). The CFCs and HCFCs which are stable chemicals persist for a long time in the atmosphere. They eventually break down in the stratosphere releasing chlorine or bromine, which in turn reacts with ozone (Earl 1990). The ability of a chemical to destroy ozone depends upon the halogen type (chlorine and bromine), the number of halogen atoms it releases and its residence time in atmosphere. Each chemical has been assigned a number according to its ozone depletion potential (ODP). The reference value is ODP = 1.0 for CFC11[8].

IV. Experimental Steup 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.

Fig.2: View of Experimental Refrigerator

Experimental System

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

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.

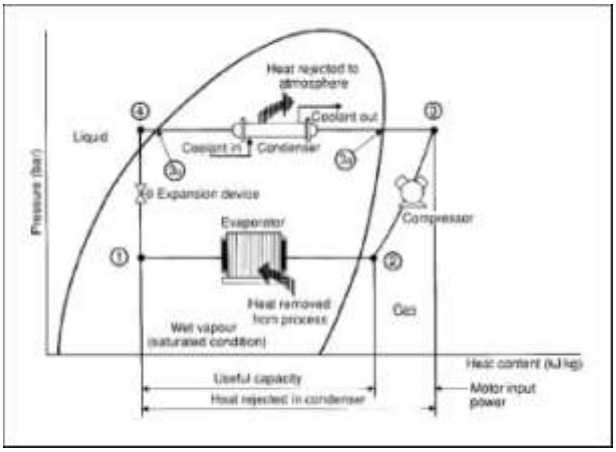

Fig.3: Schematic of a Basic vapour Compression Refrigeration System

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 vapors enter 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) DE superheats 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[3].

V. Conclusion

In developing country like India, most of the vapor compression based refrigeration, air conditioning and heat pump systems continue to run on halogenated refrigerants due to its excellent thermodynamic and thermo-physical properties apart from the low cost. However, the halogenated refrigerants have adverse environmental impacts such as ozone depletion potential (ODP) and global warming potential (GWP). Hence, it is necessary to look for alternative refrigerants to full fill the objectives of the international protocols (Montreal and Kyoto) and to satisfy the growing worldwide demand. This paper reviews the various experimental and theoretical studies carried out around the globe with environment friendly alternatives such as hydrocarbons (HC), hydroflurocarbon (HFC) and their mixtures, which are going to be the promising long-term alternatives. In addition, the technical difficulties of mixed refrigerants and future challenges of the alternatives are discussed. The problems pertaining to the usage of environment friendly refrigerants are also analyzed.

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