Comparative Performance Analysis of Domestic Refrigerator using R12, R134a and R600a Refrigerants

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ABSTRACT *Sustainable development of domestic economy is mainly depends on the energy conservation and environmental protection. The main objective of this project is focused on comparative performance analysis of domestic refrigerator using R12, R134a and R600a refrigerants. The environmental friendly refrigerants of both HC and HFC. In the group of natural refrigerants, hydrocarbons are most closely related to the HFCs. In addition to their zero Ozone depletion point and very low global warming potential, these are compatible with common materials found in refrigerating systems. Refrigerators used for domestic as well as household uses were chosen for conducting the experiments. Experiments are well planned under controlled ambient conditions to investigate the performance of VCR system operated with different refrigerants. The experimental results revealed that R600a yield higher COP and refrigeration effect compared to the other refrigerants. In conclusion, the refrigerants R134a and R600a proposed in this experimental study seems to be an appropriate long-term candidate to replace R12 as a novel refrigerant of VCR system, because of its well environmentally acceptable properties and its favourable refrigeration performances.*

Keywords: *Refrigerator, Coefficient of performance, R12, R134a and R600a.*

1. Introduction

In recent years, CFCs (chlorofluorocarbon refrigerants) are using the fluids in the domestic refrigerators .CFC contains chlorine atoms.so, these CFC refrigerants having create environmental problems and these issues are ozone depletion potential (ODP) and global warming potential. And by the year 1987 Montreal protocal tells their investigation cfc refrigerants are harmful impact on ozone layer to phase out of CFCs.by the year 1992, the Montreal protocol was improved to phase out HCFCs.in the year 1997 at Kyoto protocol was concentrating the greenhouse gases in the atmosphere should be established in which not exterming the global warming ozone layer. The chlorofluorocarbons of refrigerants (CFCs) and hydro chlorofluorocarbons (HCFCs) contribute to ozone layer depletion and global warming and have high ozone depletion potential and global warming potential. The current study focused on three alternative refrigerants for R12 these are R134aand R600a. Reddy and Kumar [1] conducted an experimental study of R134a, R406 and R600a blends as an alternative to Freon 12. The results show the ratio 50:50 of R134a/R600a mixture can be used as an alternative to R-12 in domestic refrigerator. At Te=-5^{0}C and Tc=40^{0}C , R-12 gives a COP of 2.08 while 50:50 blend of R134a/R600a gives a COP of 2.30 under the same operating conditions. [2] Refrigerant is the fluid used for heat transfer in a refrigerating system that absorbs the heat from the region during the evaporation at low temperature and pressure and heat releases from the region during condensation to a region of higher temperature and pressure. This heat transfer generally takes place phase changing the refrigerant. This research studied various refrigerants using in the refrigeration system along with their effects on the environment, and global warming. Jung et al. [3] in 2000**,** The experimental results can be obtained with same compressor indicated that the propane/isobutene mixture at 0.6 mass fraction of propane has a 3-4% higher energy efficiency and a somewhat faster cooling rate than CFC12. In conclusion, the proposed hydrocarbon mixture seems to be an appropriate long term substance to replacing CFC12/HFC134a from the viewpoint of energy conservation requiring minimum changes in the existing refrigerators. Lee and Su [4] in 2002 conducting the experimental study in the use of isobutane in a household refrigerator. The results showed that the coefficient of performance was comparing with that obtained by CFC12 and HCFC22 when used as refrigerants. Wong and Chimres [5] have investigated experimentally using hydrocarbons such as propane, butane and isobutene and their mixtures in a household refrigerator to replace HFC-134a. The household refrigerator has been designed fabrication works with R134a. The experiments for refrigerants by taking at same operating conditions. The results that hydrocarbon mixtures, propane/butane (60/40 by wt. %) respectively, is good alternative refrigerant to replaces HFC-134a. Leighton et al. [6] investigated experimentally for study predictions the performance of household refrigerators using various refrigerant

types as low GWP refrigerants such as R1234yf, R1234ze and R1234yf /R134a mixture .The investigation experimental were carried out of two states the first is Steady-state and the second transient thermodynamic models of the refrigeration system .It was found that the COP and evaporator capacity lower by about (6.2%, 8.9%), respectively, when using R1234yf as a drop-in replacement for R134a. HFO-1234yf was found to be a suitable substitute with similar performance and global warming potential is low. Bolaji [7] studied the performance of domestic refrigeration system using R12 and alternative refrigerants are R134a and R152a, showing that the coefficient of performance (COP) of the domestic refrigeration system using R152a was very close to that of R12 with only 1.4% reduction, while that of R134a is low with 18.2% reduction.

Halimic et.al [8] showed the cooling capacity of R290 was the largest of the refrigerants tested, and higher than the original refrigerant R12.also showed that COP of system with R290 is very similar to that of R12 thus it can be said that it represents an attractive alternative to existing CFCs in small domestic refrigerators. Most of the previous studies focused on the increasing the performance with their blend mixtures and their alternate refrigerants. Comparative performance analysis of domestic refrigerator using R12, R134a and R600a refrigerants. Chesi et al. [9] analyzed the solar assisted vapour compression cooling system and they implemented the numerical model in order to simulate the behaviour of solar capitation circuit, ejection cycle and conventional cycle. The results revealed that the simulated system, which includes 100 m2 of solar collectors, a 5 m3 water thermal storage and an ejector with 6.5mmprimary throat diameter, is able to increase the average yearly COP of the conventional vapour compressor system by 15%, with a solar fraction of 0.76 for a constant 1 kW cooling load. Mohanraj [10] assessed the performance of domestic refrigerator using R430a as a possible alternative refrigerant to R134a. The performance has been assessed for three different condensing temperatures, specifically, 40, 50 and 60 °C with a wide range of evaporator temperatures between −30 and 0 °C. The performance of the domestic refrigerator was compared in terms of volumetric cooling capacity, coefficient of performance, compressor power consumption and compressor discharge temperature. The results confirmed that R430A is an energy efficient and environment-friendly alternative to R134a in domestic refrigerators. The results reported by some researchers that, R134a and R600a refrigerants has higher coefficient of performance and lower compressor discharge temperature and pull down time as compared to R12.Hence, the present work is aimed to evaluate the comparative performance of VCR system using the refrigerants of R12, R134a and R600a operating at same environmental conditions.

2. VCR system working principle and construction

Refrigeration system is based upon the Clausius statement of second law of Thermodynamics. This statement shows, "It is impossible to construct a de vice which, operating in a cycle, will produce no affect other than the transfer of heat from a cooler to a hotter body. The line diagram of simple VCR cycle is shown in Fig.1 and the various processes involved in vapour compression refrigeration systems are also presented with the help of P-H diagram as shown in Fig.2.

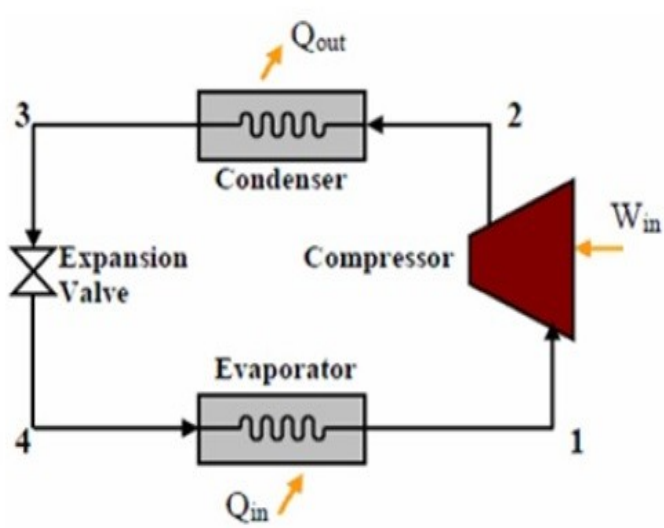

Fig.1. Simple VCR system

The pressure-enthalpy (*p-h*) diagram is a thermodynamic property diagram commonly used in the refrigeration field.
Process 1 – 2: Isentropic compression in compressor.
Process 2 –3: Constant pressure heat rejection in condenser.
Process 3 – 4: Isenthalpic expansion in expansion device.
Process 4 – 1: Constant pressure heat absorption in evaporator.

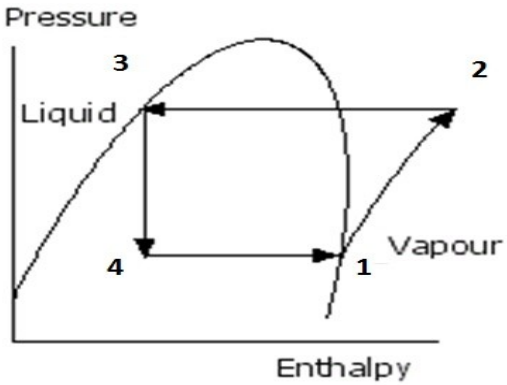

Fig.2. P-h Diagram of simple VCR cycle

From the pressure-enthalpy diagram the following parameters can be evaluated.

The amount of heat rejected in the condenser is calculated by

$$Qcon = m_r (h_2-h_3) \quad (1)$$

The power input to drive the compressor is given by

$$W= m_r (h_2-h_3) \quad (2)$$

The cooling capacity of the evaporator is given by

$$Qeva= m_r (h1-h_4) \quad (3)$$

The COP is the ratio between the amounts of heat absorbed in the evaporator to the power required to run the compressor. The COP can be expressed as

$$COP= m_r (h_1-h_4) / m_r(h_2-h_1) \quad (4)$$

3. Experimental setup of VCR system

In this experimental setup initially, the compressor is run with conventional electrical power. Tests are to be conducted at same condenser and evaporator temperatures for all the refrigerants in order to compare the performance parameters of the refrigerator. The different instruments like Pressure gauges, Thermocouples, Voltmeters and Ammeter are used to measure pressure, temperature, voltage and current respectively during experimentation. Thermocouple sensor of RTD PT100 type is used, which directly gives the value of temperature at various points in the vapour compression refrigeration system. Initially, VCR system is charged with R12 refrigerant and conducts the tests at different operating conditions to generate base data. In the next stages, R134a and R600a refrigerant is charged the VCR system and done the similar tests and experimental data were recorded. The experimental results are to be analyzed to know the performance of vapor compression refrigeration system. The experimental is designed and is used to find the COP of Domestic refrigerator. Figure shows the designing of the experimental setup. Hemispheric sealed type compressor is used in the system, the forced convection air cooled condenser, expansion value and

evaporator are the components of domestic refrigerator are shown in the Fig.3. The compressor usually has a capacity of $1/8^{th}$ of its regular value. Using pressure gauges in the system to find the inlet and outlet pressures and temperatures of refrigerant in the compressor. The Sub-Zero temperature indicator is used to measure the various temperatures such as condenser inlet (T1), condenser outlet (T2), evaporator inlet (T3) and evaporator outlet (T4).

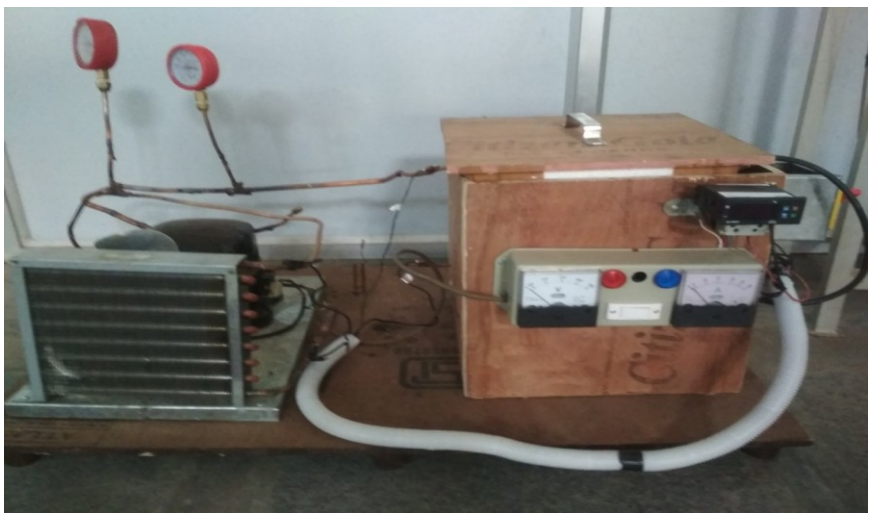

Fig.3. Experimental set up of the VCR system test rig**.**

4. WORKING REFRIGERANTS AND THEIR PROPERTIES

This present research work mainly focuses on the comparative performance of vapour compression refrigeration system powered with different refrigerants such as R12, R134a and R600a operating under same environmental conditions.

i) **R12:** The R12 refrigerant is a non-toxic, non-flammable and non-explosive. But it is CFCs refrigerant and creating environmental issues such as ozone depletion and global warming potential and to contribute the rise in a sea level.

ii) **R134a:**R134a is the refrigerant which is used as long-term replacement of R12 refrigerants and its favourable parameters such as zero ODP, non-flammability, compared to that of R12. The R134a ozone depleting potential is zero, but it has high GWP when comparing other refrigerants.

iii) **R600a:** R600a is derived from natural ingredients is the advantage of this refrigerant, low power consumption, slow low temperature rising speed and strong cooling performance.

Fig.4.Photographic view of refrigerants R12, R134a and R600a

The physio-chemical properties of tested refrigerants such as R12, R134a and R600a are presented in Table 1.

Table1 properties of refrigerants

Trade name	R12	R134a	R600a
Chemical formula	CF_2CL_2	CH_2FCF_3	C_4H_{10}
Lubricant	Mineral oil	Polyester	Mineral oil
Normal boiling Point($0^{c)}$	-29.8	-26.1	-11.73
Critical pressure(bar)	41.15	40.59	3.65
Critical Temperature($0^{c)}$	112	101.1	134.7
Critical Density(kg/m^3)	558	511.9	224.4
Molecular Weight(kg/kmol)	120.93	102.02	58.12
Latent heat of evaporation(kj/kg)	165.1	215.9	386
ODP	1	0	0
GWP	8500	1300	4

5. RESULLTS AND DISCUSSIONS

5.1Refrigeration effect variation

The Refrigeration effect of the VCR system for tested refrigerants is shown in Fig.5. The refrigerant effect of the refrigerator using R12, R134a and R600a is considering the refrigerants and compared their refrigeration effect. The experimental test results reveals that refrigeration effect is significantly higher for R600a refrigerant when compared to R12 and R134a operating at same environmental conditions.

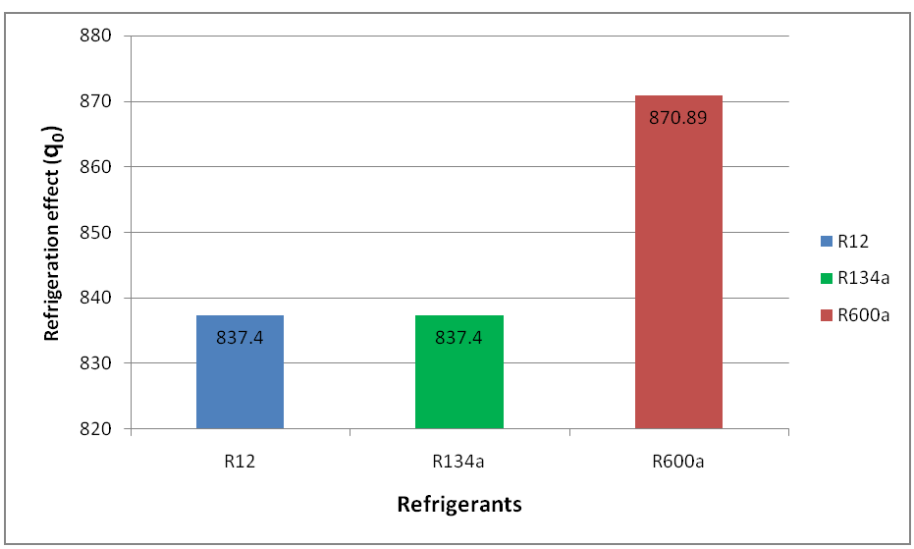

Fig.5. Variation of refrigeration effect for various refrigerants of VCR system

5.2 Coefficient of performance variation (COP)

The variation of coefficient of performance (COP) of vapour compression refrigeration system powered with different refrigerants is presented in Fig.6. Comparing of coefficient of performance of Domestic refrigerator by using three refrigerants such as R12, R134a and R600a (isobutene). The COP of R12 refrigerant is higher when compared to other refrigerants tested in this experimental work. However, the COP of R600a is almost nearer to the COP of R12. Isobutene is better performance of natural ingredient refrigerant, and the cop of R134a refrigerant is lower than the R12, R600a refrigerants.

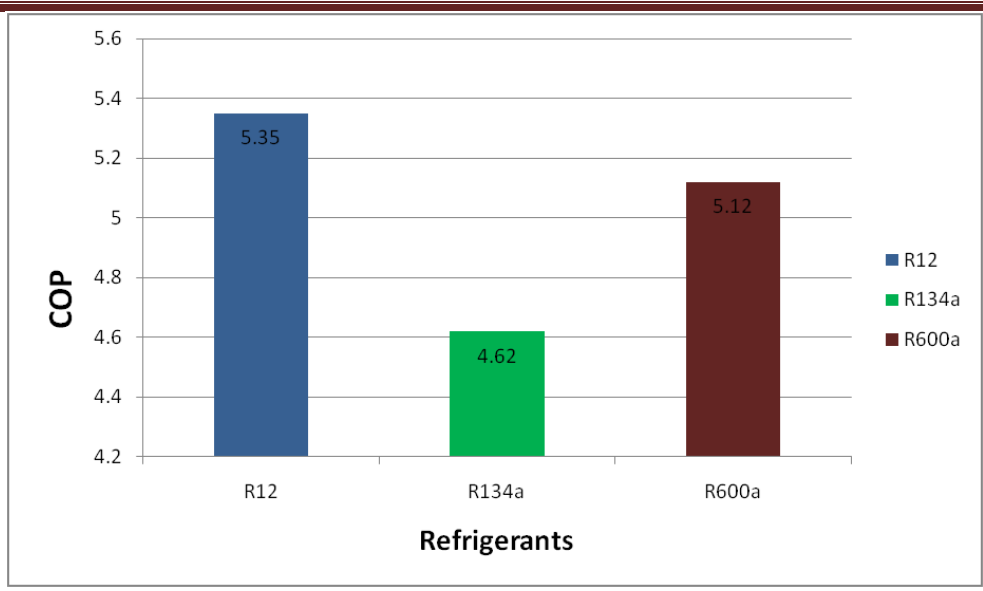

Fig.6. Variation of COP for various refrigerants of VCR system

6. Conclusions

For several industrial applications, many refrigerants have been carried out according the specific request. The study was focused on COP criteria as a new way Comparative evaluation of different refrigerants such as R12, R134a and R600a to check the VCR simple cycle and system's components. The experiments were conducted smoothly on VCR system with different refrigerants. The test results of VCR system indicates that COP and Refrigeration effect of R600a is significantly higher than other tested refrigerants. Refrigerant R600a is a natural Ingredient refrigerant with zero ODP and negligible GWP. However the main drawback of R600a is flammability refrigerant which contribute towards the environmental issues and climate change. and protect the ozone layer. R600a refrigerant is an environment friendly refrigerant and global warming potential gets reduced. Vapour pressure characteristics of R134a and R600a closely match with R12, thus same compressor can be used. Thus R600a refrigerant might be used as a new alternative in Vapour Compression Refrigeration (VCR) simple cycle.

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