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COMPARATIVE ANALYSIS OF PERFORMANCE OF OZONE-FRIENDLY AND LOW GWP HFC REFRIGERANT IN A VAPOUR COMPRESSION REFRIGERATION CYCLE

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Abstract:-

Theoretical performance analysis on a vapour compression refrigeration system with R152a a potential replacement for the R134a was done and results obtained with both refrigerants were compared. Both the refrigerants have same zero ODP but the GWP of R152a is ten times lower than R134a.The results showed that the R152a have a slightly higher (3.769%) coefficient of performance (COP) than R134a for the condensation temperature of 51 ^{0}C and three different evaporating temperatures. The effects of the main parameters of performance analysis such as Refrigerating Effect, Compressor Work, Power Per Ton of Refrigeration (PPTR) were investigated for various evaporating temperatures. The graphs plotted provide satisfactory explanations about the effect of various system variables on the performance of a vapour compression refrigeration system.

Keywords*: *alternative refrigerant, R152a, R134a, ODP, GWP, performance analysis

I. INTRODUCTION

While developing new refrigerants or finding alternative the first major concern is depletion of ozone layer. Ozone layer is a layer which protects the earth from ultraviolet rays. Ozone depletion potential is evaluated on a scale that uses CFC-11 as a benchmark. All the other components are based on how damaging to the ozone they are in relation to CFC-11. [7] The second major concern is global warming. Global warming is the increase in global earth surface temperature due to the absorption of infrared emission from earth surface. Global warming potential is evaluated on a scale that uses CO_2 as the bench mark i.e. CO_2 is assigned a value and other components are compared to CO_2. [1]

In 1987, the Montreal Protocol, an international environmental agreement, established requirements for the worldwide phase out of ozone depleting CFCs. The use and production of CFCs have been phased out in developed and developing countries since January 1996 and 2010, respectively. [18]

Initial alternative to CFCs included some hydro-chlorofluorocarbons (HCFCs), but they will also be phased out internationally by year 2020 and 2030 in developed and developing nations respectively, because their ozone depletion potentials (ODPs) and global warming potentials (GWPs) are in relative high levels though less than those of CFCs. HFCs which are widely used now days for the alternatives for high ODP CFCs and HCFCs. But the major disadvantage of HFCs is that they are also form a part of other five gases which are targeted as green house gases in Kyoto Protocol. Kyoto Protocol signed by many countries in 1997 aims to phase out emission of greenhouse gases. HFC R134a is widely used nowadays in domestic and industrial refrigeration which have zero ODP but global warming potential of 1300 per 100 years, which is very high. The fluorine atoms in HFC134a are responsible for the major environmental impact (GWP) with serious implications for the future development of alternative for the same. [16]

A number of investigators compared the performance of R134a and its potential alternative R152a. The experiment performed by A.Baskaran and P.Koshy Mathews on vapour compression refrigeration system shows 3.46% higher COP in case of R152a than that of 134a. The experiment was performed at 50^0C condenser temperature and -10^0C evaporator temperature.[10] Bukola Olalekan Bolaji, Zhongjie Huan and Francis Olusesi Borokinni performed study of eco-friendly R152a and R600a as alternative refrigerants in the vapour compression refrigeration system. Their experimental results obtained shows average COP of R152a is 13.4% higher than R134a. Similarly average refrigerating effects obtained for R152a and R134a are 244.7 kJ/kg and 136.1 kJ/kg respectively.[14] The present study mostly concentrates on a theoretical investigation on the performance of the vapour compression refrigeration cycle. The potential alternative R152a was used for comparison with the conventional refrigerant R134a.The effects of the main parameters of performance analysis such as type of refrigerant, refrigerating effect, compressor work, volumetric refrigerating capacity, power per ton of refrigeration and COP for various evaporating temperatures and a constant condensation temperature of 51^0 C.

Table 1. Some Properties and environmental impact of R134a and R152a [3]

Refrigerants	R134a	R152a
Chemical Formula	$C_2H_2F_4$	$C_2H_4F_2$
Boiling Point (^{0}C)	-26.1	-24
ODP	0	0
GWP	1300	120

II. EXPERIMENTATION

A. Theoretical Analysis

The p-h diagram shown in Fig.1 is frequently used in the analysis of vapour compression refrigeration cycle. In the refrigeration system, the representative performance characteristics are compressor power (W_C) in kJ/kg, refrigerating effect (RE) kJ/kg and Coefficient of Performance (COP).A vapor compression cycle is used in most water cooler, refrigerator and deep freezers. In this cycle, a circulating refrigerant such as R134a enters a compressor as low pressure vapor. The vapor is compressed isoentropically (1-2) and exits the compressor as high-pressure superheated vapor. The superheated vapor travels under pressure through coils or tubes comprising 'the condenser', which are passively cooled by exposure to air in the room. The condenser cools the vapor, which liquefies in constant pressure heat rejection process (2-3) in condenser. As the refrigerant leaves the condenser, this liquid refrigerant is forced through a metering or throttling device, also known as an expansion device (capillary tube) to an area of much lower pressure. The sudden decrease in pressure results in explosive-like flash evaporation of a portion (typically about half) of the liquid. This process of expansion is Isenthalpic expansion (3-4). The latent heat absorbed by this flash evaporation is drawn mostly from adjacent still-liquid refrigerant, a phenomenon known as 'auto-refrigeration'. This cold and partially vaporized refrigerant continues through the coils or tubes of the evaporator unit. The process is constant pressure heat absorption. (4-1). Refrigerant leaves the evaporator, now fully vaporized and slightly heated, and returns to the compressor inlet to continue the cycle. [1]

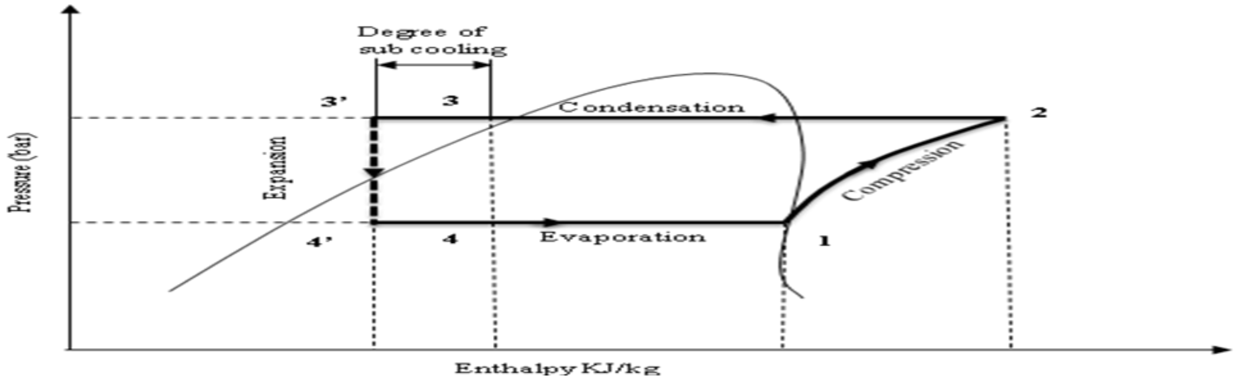
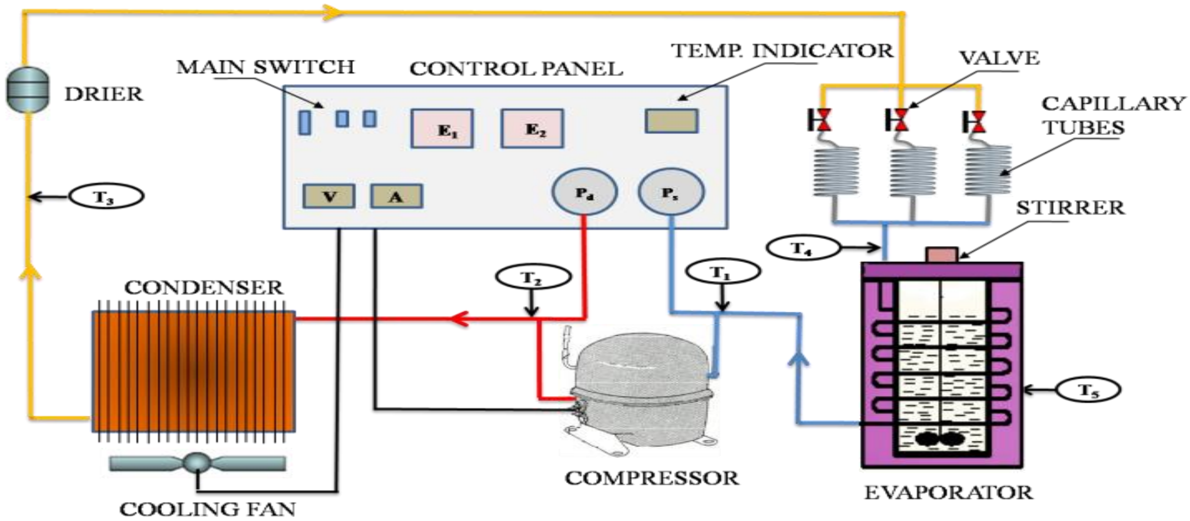


Fig 1. Vapour compression refrigeration system on p-h diagram.

B. Experimental Setup

The Experiment model used to compare the performance of the refrigerants is single stage simple vapour compression refrigeration cycle consisting of compressor, condenser, capillary tube as expansion device and evaporator. The schematic diagram of the vapour compression refrigeration cycle is shown in Fig 2.The system was instrumented with hermetically sealed reciprocating type compressor. It is originally designed for



R134a refrigerant. The input power of the compressor within the system varied between 230 and 300 W. The major ingredient of the compressor lubricant was mineral oil. A POE (Polyolester Oil) drier filter was used to absorb the moisture. Compact forced air cooled type condenser was used for their good heat transfer performances. Three capillary tubes with diameter 1.269 mm, 1.117 mm & 0.914 mm are used with variable flow device. Evaporator section was made by shell and tube type, by copper tubes and stainless steel tank. For minimizing the heat loss, the evaporator tank was well insulated by Nitrile Foam Rubber. The refrigerants used were R134a and R152a. Some other measuring and controlling components were used in the system, that were, an electrical switch, 1 KW electric heater with dimmer and stirrer for controlling the evaporator temperature, an energy meters for heater and compressor with accuracy of ± 0.2 kWh, a voltmeter, an ampere meter, two pressure gauges with accuracy of ±0.5 psi at the inlet and outlet of the compressor for measuring the suction and discharge pressures, 'Pt100' type thermocouples (Range -50℃ to 750℃) with accuracy of ±0.1°C at five points, indicator and gas flow control valves. The system was charged with the help of charging system and compressor service port and evacuated with help of vacuum pump to remove the moisture. After charging each refrigerant, data were collected at various evaporator temperatures and the following performance parameters were obtained in terms of refrigerating effect, compressor work input (W_{comp}), Coefficient of Performance (COP), and Power per Ton of Refrigeration.

3.3 Data Reduction

The data reduction of the theoretical results considering the cycle on p-h diagram in Fig.1,

The heat absorbed by the refrigerant in the evaporator or refrigerating effect (Q_{evap}, kJ/kg) is calculated as:

$$Q_{evap} = (h_1 - h_4) \quad (1)$$

Where, h_1 = specific enthalpy of refrigerant at the outlet of evaporator (kJ/kg); and h_4 = specific enthalpy of refrigerant at the inlet of evaporator (kJ/kg).

The compressor energy input (W_{comp}, kJ/kg) is obtained as:

$$W_{comp} = (h_2 - h_1) \quad (2)$$

Where, h_2 = specific enthalpy of refrigerant at the outlet of compressor (kJ/kg). The process 3 to 4 is at constant enthalpy process. Therefore,

$$h_3 = h_4 \quad (3)$$

Where, h_3 = specific enthalpy of refrigerant at the outlet of condenser (kJ/kg).

The Coefficient of Performance (COP) is the refrigerating effect produced per unit of energy required; therefore, COP is obtained as the ratio of Eq. (1) to Eq. (2):

$$COP = \frac{Q_{evap}}{W_{comp}} \quad (4)$$

Power Per Ton of Refrigeration (PPTR) in KW/TR is obtained as:

$$COP = \frac{3.5\, W_{comp}}{Q_{evap}} \quad (5)$$

IV. RESULTS AND DISCUSSIONS: By keeping condenser temperature constant at 51^0 C and varying evaporator temperature behavior of the refrigerants in the vapour compression refrigeration system is analyzed considering the following points: refrigerating effect, compressor work, evaporator pressure, power per ton of refrigeration, volumetric refrigeration capacity and COP. All these values are calculated by considering unit mass flow rate in the system.

A. Evaporator Pressure

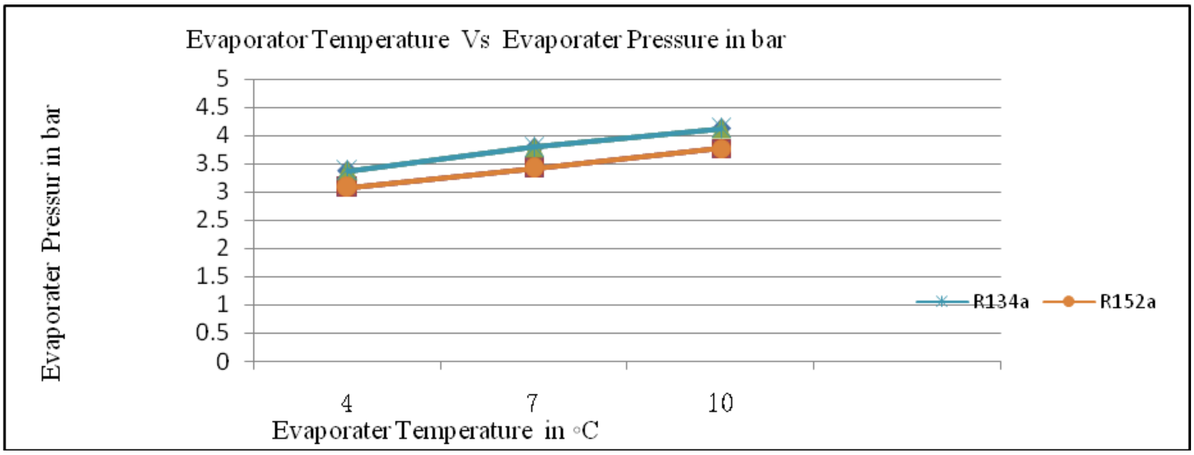


Fig.3: Variation of Evaporator Pressure with varying Evaporator Temperature for R152a and R134a.

Figure 3 illustrates the variation of the evaporator pressure as a function of the evaporator temperature for the two refrigerants. R152a has the lowest pressure with mean pressure lower than 9.9 % that of R134a. The pressure of R152a was very close to that of R134a. Refrigerant with low pressure is desirable in the system because the higher the pressure the weightier must be the equipment parts and accessories.

B. Refrigerating Effect

As shown in the fig 4, refrigerating effect increases as the evaporating temperature increases for both refrigerants. This is due to the increase in latent heat value of the refrigerant. A very high latent heat value is desirable since the mass flow rate per unit of capacity is less. When the latent value is high, the efficiency and capacity of the compressor are greatly increased. This decreases the power consumption and also reduces the compressor displacement requirements that permit the use of smaller and more compact equipment. It is clearly shown in Fig 3 that R152a exhibited higher refrigerating effect than R134a. Therefore, very low mass of refrigerant will be required for the same capacity and compressor size. The refrigerating effect highest average value of (246.24 kJ/kg) was obtained using R152a compare with (156.12 kJ/kg) of R134a at condensing temperature of 51^0C.

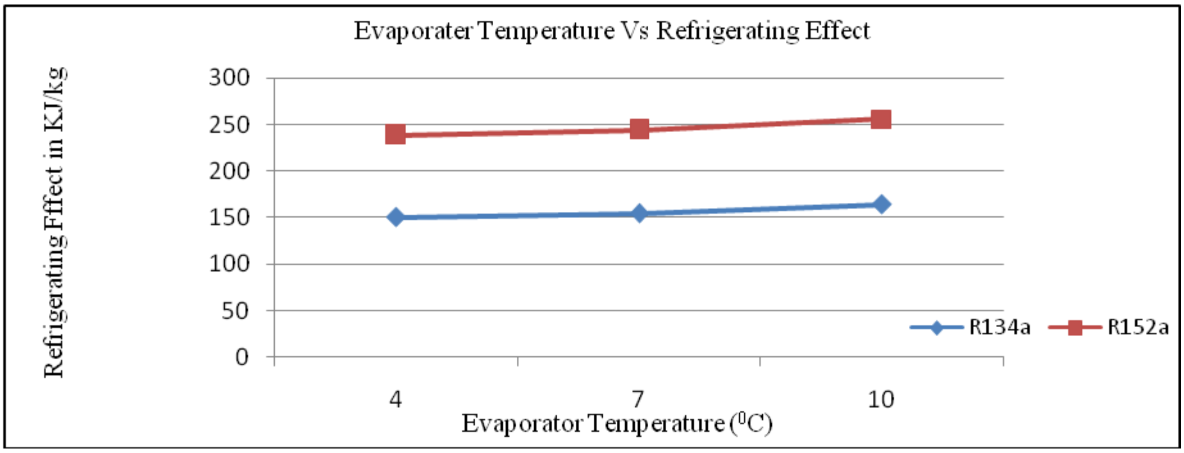


Fig 4: Variation of Refrigerating Effect with varying Evaporator Temperature for R152a and R134a

C. Compressor Work

Figure shows the variation of the compressor Work with evaporating temperature for R134a and its alternative refrigerant R152a at condensing temperature of 51^{0}C. Figure shows that the compression Work decreases as the evaporating temperature increases. This is due to the fact that when the temperature of the evaporator increases the suction temperature also increases. At high suction temperature, the vaporizing pressure is high and therefore the density of suction vapour entering the compressor is high. Hence the mass of refrigerant circulated through the compressor per unit time increases with the increases in suction temperature for a given piston displacement. The increase in the mass of refrigerant circulated decreases the

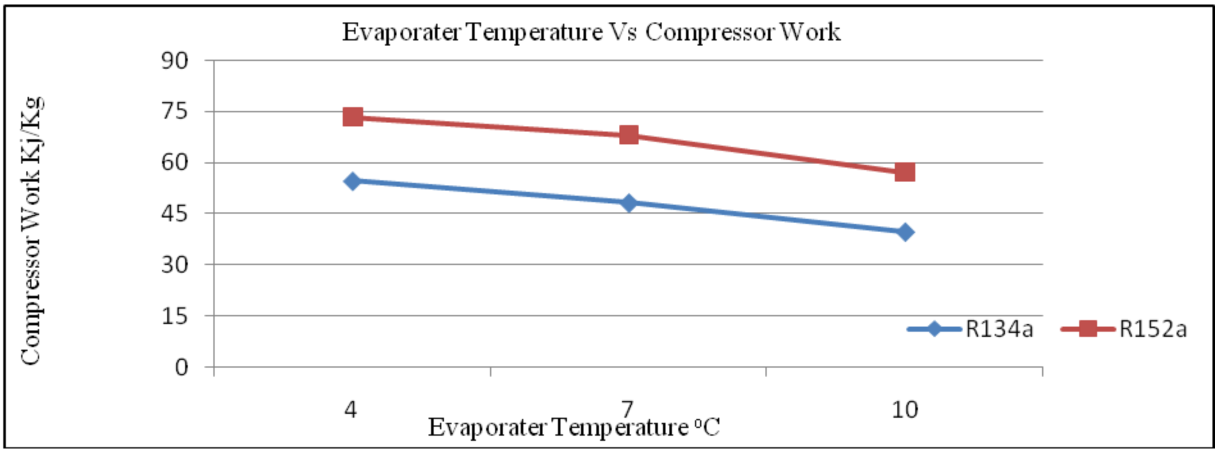


Fig. 5: Variation of Compressor Work with varying Evaporator Temperature for R152a and R134a.

work of compression. The R152a exhibited higher compressor Work than R134a (Graph 3) and it is 39.46% higher than the compressor work for R134a.

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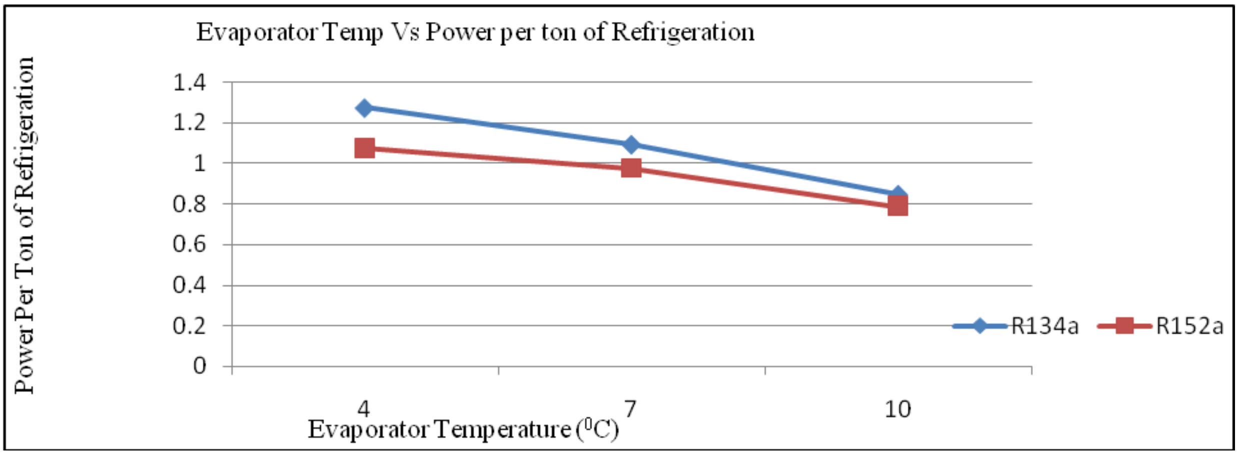
D. Power Per Ton of Refrigeration

The influence of evaporating temperature on the power consumption per ton of refrigeration at condensing temperature of 51°C for R134a and the investigated alternative refrigerant R152a is shown in figure. Power per ton of refrigeration reduces as the evaporating temperature increases for both the investigating refrigerants. In this result, R152a has emerged as the most energy efficient refrigerant among both the investigated refrigerants being the one that exhibited the lowest power consumption per ton of refrigeration with the average value of 13.23% less than that of R134a.



refrigerants. As shown in this fig.7 R152a and R134a have difference between discharge temperature of R152a and R134a is 3.36 %.

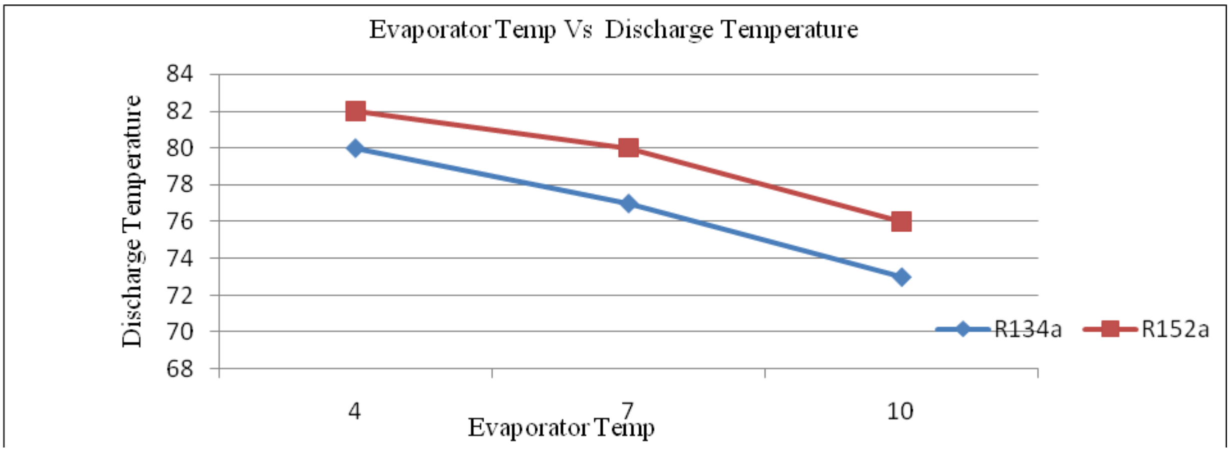


Fig 7: Variation of Compressor Work with varying Evaporator Temperature for R152a and R134a.

The advantage of a lower discharge temperature is that there will be less strain on the compressor and hence a longer compressor life. In addition the oil is less likely to break down.

F. Coefficient of Performance

The coefficient of performance (COP) of a refrigeration cycle reflects the cycle performance and is the major criterion for selecting a new refrigerant as a substitute. The COPs for R134a and R152a refrigerants at varying evaporator temperature for condensing temperature of 51^{0}C are shown in fig 8. COP increases with increase in evaporator temperature. As clearly shown in the fig 8 R134a has the lower COP as that of R152a at same evaporator temperature. R152a has the COP with average value of 3.769% higher than that of R134a.

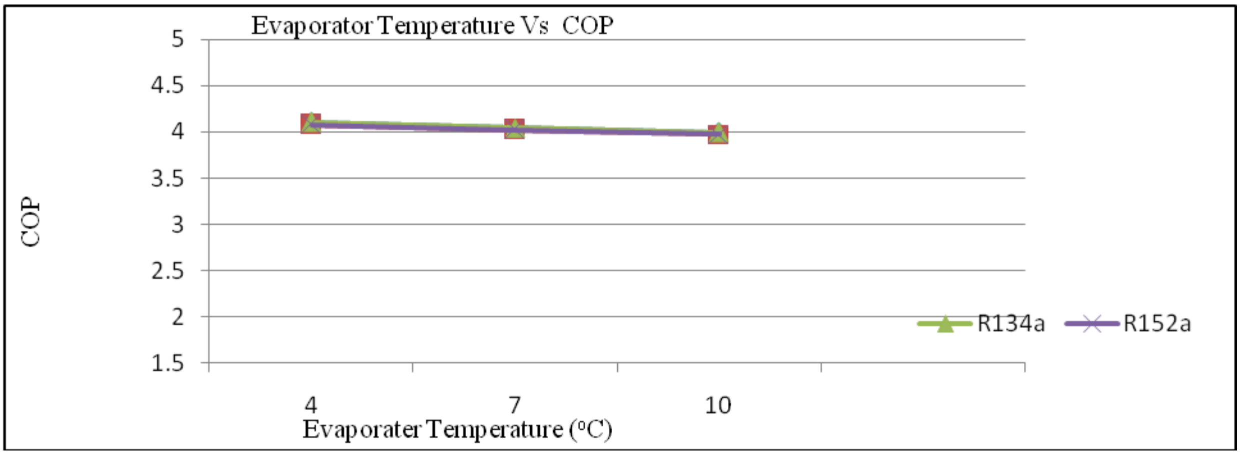


Fig 8: Variation of COP with varying Evaporator Temperature for R152a and R134a

V. CONCLUSIONS

In this study, an ideal vapor-compression system is used for the performance analysis of alternative new refrigerant. R152a substitute for R134a in a vapour compression refrigeration system at varying evaporating temperature and condensing temperature of 51^{o}C. The following conclusions can be drawn from the analysis and discussion of the results:

i. Out of the two refrigerants investigated, R152a offers the best desirable environmental requirements; it has zero Ozone Depletion Potential (ODP) and 120 Global Warming Potential (GWP) which is lesser ten times that of R134a.

ii. The evaporator pressure and temperature characteristic profile of R152a is close to the evaporator pressure curve of R134a. It is 9.9 % higher than R134a. Therefore, R152a will work perfectly as R134a substitute.

iii. R134a exhibited lower compressor energy input than R152a, but R152a exhibited significantly high refrigerating effect, which is a form of compensation for its high compressor energy input.

iv. R152a emerged as an energy efficient refrigerant with average Power Per Ton of Refrigeration (PPTR) of 13.23% less than that of R134a.

v. R152a has the higher COP. The average COPs obtained for R152a were 3.769% higher than that of R134a.

vi. R152a refrigerant has approximately the same performance with R134a, therefore, R152a is considered as a good drop-in substitute for R134a in vapour compression refrigeration system. The best performance was obtained from the use of R152a in the system.

REFERENCES

Sandip P. Chavhan, Prof. S. D. Mahajan, *"A Review of an Alternative to R134a Refrigerant in Domestic Refrigerator",* International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 9, September 2013.

R. Cabello, E. Torrella, J. Navarro-Esbri, *"Experimental evaluation of a vapour compression plant performance using R134a, RR407C and R22 as working fluids"*, Applied Therma Engineering 24 (2004) 1905-1917.

B.O.Bolaji, M.A. Akintunde, T.O. Falade, *"Comparative analysis of performance of three ozone-friends HFC refrigerants in a vapour compression refrigerator*", Journal of Sustainable Energy and Environment 2 (2011) 61-64.

B.Bolaji, *"Selection of environment-friendly refrigerants and the current alternatives in vapour compression refrigeration systems"*, Journal of Science and Management, Vol. 1, No. 1 (2011) 22-26.

James M. Calm, *"Emissions and environmental impacts from air-conditioning and refrigeration systems,"* International Journal of Refrigeration 25, pp.293–305,2002.

P.L.Ballaney, "*Refrigeration and Air conditioning",* Khanna Publishers,2009

Eric Granryd, *"Hydrocarbons as refrigerants - an overview,"* International Journal of Refrigeration.24,pp.15-24,2001

Y.S. Lee, and C.C. Su, *"Experimental studies of isobutene (R600a) as the refrigerant in domestic refrigeration system,"* Applied Thermal Engineering 22, pp. 507–519, 2002.

Mao-Gang He, Tie-Chen Li, Zhi-Gang Liu, and Ying Zhang, *"Testing of the mixing refrigerants HFC152a/HFC125 in domestic refrigerator,"* Applied Thermal Engineering 25, pp. 1169–1181, 2005.

A.Baskaran, P.Koshy Mathews, *"A Performance Comparison of Vapour Compression Refrigeration System Using Eco Friendly Refrigerants of Low Global Warming Potential",* International Journal of Scientific and Research Publications, Volume 2, Issue 9, September 2012 ISSN 2250-3153

Ki-Jung Park, and Dongsoo Jung, *"Thermodynamic performance of HCFC22 alternative refrigerants for residential air-conditioning applications,"* Energy and Buildings 39, pp. 675–680, 2007.

K. Mani, and V. Selladurai, *"Experimental analysis of a new refrigerant mixture as drop-in replacement for CFC12 and HFC134a,"* International Journal of Thermal Sciences 47, pp. 1490–1495, 2008.

A.S. Dalkilic, and S. Wong wises, *"A performance comparison of vapour-compression refrigeration system using various alternative refrigerants,"* International Communications in Heat and Mass Transfer 37, pp. 1340–1349, 2010.

Bukola Olalekan Bolaji, Zhongjie Huan, Francis Olusesi Borokinni, *'Energy Performance of Eco-friendly R152a and R600a Refrigerants as Alternative to R134a in Vapour Compression Refrigeration System"*, ISSN. 1453 – 7397,2014

Minxia Li, Chaobin Dang, and EijiHihara, *"Flow boiling heat transfer of HFO1234yf and R32 refrigerant mixtures in a smooth horizontal tube: Part I. Experimental investigation,"* International Journal of Heat and Mass Transfer 55, pp. 3437–3446, 2012.

Dr.S.N.Sapali, "*Refrigeration and Air conditioning PHI Learning"*, Eastern EconomyEdition,2009.

Dr. Roberto de Aguiar Peixoto, "*Manual for Refrigeration Servicing Technicians"*, ISBN: 978-92-807-2911-5

Mahmoud Ghodbane, "*An Investigation of R152a and Hydrocarbon Refrigerants in Mobile Air Conditioning"*, SAE Technical Paper Series 1999-01-0874