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"Experimental Performance Evaluation Of Vapour Compression Refrigeration System using R134a and R152a Refrigerants, A review"

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ABSTRACT

There is increasing concern in India and other countries that global warming is growing in its effect. The global warming impact of a refrigerant relative to CO2 can be measured by its GWP. R134a was initially assessed as having a GWP of 1300 (IPCC 2001) and later assessed to have a GWP of 1430 (IPCC 2007). This is thought to be disconcertingly high and has prompted a search for alternatives. The European Union (EU) is one body that has taken the course of proceeding down the legislative path in order to try to address possible future consequences of global warming. Under the legislation, the replacement refrigerants must have a GWP of less than 150 (Vainio 2006).

Industry has begun searching for alternatives with a lower global warming potential (GWP). So there is urgent need of alternative refrigerants to R134a. R-152a is a more environmentally benign refrigerant compared to R-134a with a GWP of 120. Both refrigerants are hydro-fluorocarbons(HFCs) - (contain no chlorine) and hence, have zero ozone depletion potential. R152a have some flammability issues but have no ozone depletion potential and have a significantly lower GWP. R152a is energy efficient than R134a. Project work will deal with test a Vapor Compression Refrigeration System using the two likely drop-in candidate refrigerants R134a and R152a in representative environments under controlled conditions. Performance Parameters such as COP, Cooling capacity, condenser capacity, energy efficiency etc. will be analyzed. Comparison of various properties for refrigerants R152a and R134a will be done for a Vapor Compression Refrigeration System.

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I. INTRODUCTION

A vapor compression refrigeration system is an improved type of air refrigeration system in which a suitable working substance, termed as refrigerant is used. It condensed and evaporates at temperatures and pressures close to the atmospheric conditions. Compression refrigeration cycles take advantage of the fact that highly compressed fluids at a certain temperature tend to get colder when they are allowed to expand. If the pressure change is high enough, then the compressed gas will be hotter than our source of cooling (outside air, for instance) and the expanded gas will be cooler than our desired cold temperature. In this case, fluid is used to cool a low temperature environment and reject the heat to a high temperature environment. In the general vapor compression system four processes are involved. In the first process isentropic compression of the refrigerant in compressor takes place. In the second process constant pressure heat rejection of refrigerant in condenser takes place. In the third process Isenthalpic expansion of refrigerant in expansion device takes place. In the fourth process Constant pressure heat absorption in evaporator takes place.

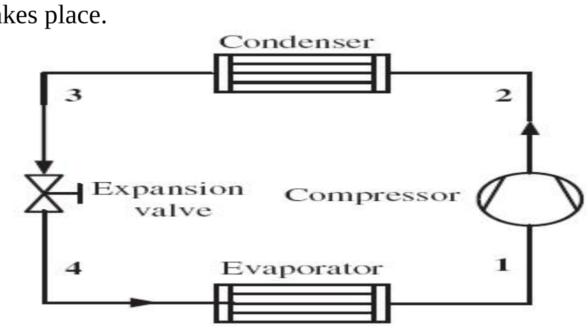

Fig-1 Schematic of the Vapor Compression Refrigeration System[1]

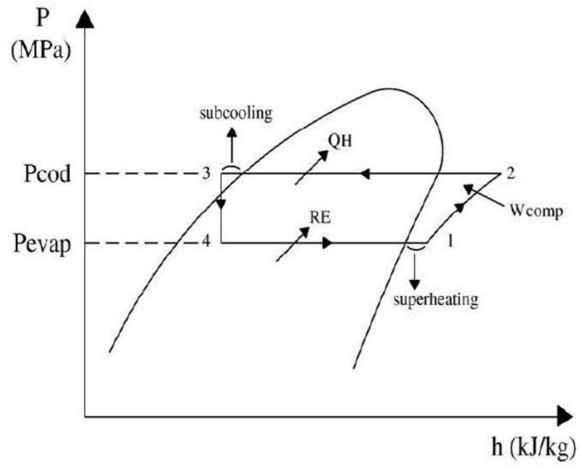

Figure-2 Pressure-enthalpy graph for vapor compression refrigeration system[10]

Process 1 – 2: Isentropic compression in compressor. The vapor refrigerant at low pressure p1 and temperature T1 is compressed isentropically to dry saturated vapor as shown by the vertical line 1-2 on T-s diagram and by the curve 1-2 on p-h diagram. The pressure and temperature rises from 1 to 2. The work done during isentropic compression is given by:

Process 2 –3: Constant pressure heat rejection in condenser. The high pressure and temperature vapor refrigerant from the compressor is passed through the condenser where it is completely condensed at constant pressure p2 and temperature T2. The vapor refrigerant is changed into liquid refrigerant. The refrigerant while passing through the condenser, gives its latent heat to the surrounding condensing medium.

Process 3 – 4: Isenthalpic expansion in expansion device. The liquid refrigerant at pressure p3=p2 expanded by throttling process through the expansion valve to a low pressure p4=p1 and temperature T4=T1. Some of the liquid refrigerant evaporates as it passes through expansion valve, but the greater portion is vaporized in the evaporator. During the throttling process no heat is absorbed or rejected by the liquid refrigerant.

Process 4 – 1: Constant pressure heat absorption in evaporator. The liquid vapor mixture of the refrigerant at pressure p4=p1 and temperature T4=T1 is evaporated and changed into vapor refrigerant at constant pressure and temperature. During evaporation, the liquid vapor refrigerant absorbs its latent heat of vaporization from medium (air, water or brine) which is to be cooled.

II. LITERATURE REVIEW

Yinhai Zhu, Peixue Jiang[1] developed which combines a basic vapor compression refrigeration cycle with an ejector cooling cycle. The ejector cooling cycle is driven by the waste heat from the condenser in the vapor compression refrigeration cycle. The additional cooling capacity from the ejector cycle is directly input into the evaporator of the vapor compression refrigeration cycle. The results show that the COP is improved by 9.1% for R22 system.

Ankit Tiwari[2] performances of four ozone-friendly Hydro fluorocarbon (HFC) refrigerants (R125, R134a, R143a and R152a) selected to replace R12 in a vapor compression refrigeration system were investigated experimentally and compared. The performances were evaluated for the investigated refrigerants at various evaporating and condensing temperatures. The results obtained showed that the investigated refrigerants confirmed that R152a and R134a have approximately the same thermodynamic performances similar to R12 while deviation of R125 and R143a were very large. But the best performance was obtained from the used of R152a in the system. As a result, R152a could be used as a drop-in replacement for R134a in vapor compression refrigeration system. The COP of R152a obtained was higher than those of R12, R125, R134a, R143a.

Bukola Olalekan Bolaji[3] performance of alternative refrigerants in an adiabatic capillary tube was investigated experimentally in a vapor compression refrigeration system. The mass flow rate was determined at a series of condensing temperatures, varying degree of sub-cooling, and at various lengths of capillary tube. The average mass flow rate of R152a and R134a were 1.2 % lower and 1.9 % higher than that of R12 respectively, under the same operating conditions. The coefficient of performance (COP) obtained using R134a and R152a refrigerants was very close to that of R12 with only 2.6 % and 1.3 % reduction, respectively, while the COPs obtained using R23, R32 and R143a were significantly very low. The performance obtained in a refrigeration system differs among individual selected alternative refrigerants. The differences are larger for R143a, R32 and R23, and the deviation from the performance of R12 is in that order, while the differences are smaller or negligible for R134a and R152a. The best overall performance is obtained using R152a.

Gaurav, Raj Kumar[4] The paper analyzes the domestic refrigerator with alternative refrigerants for computing coefficient of performance, exergy destruction ratio, exergy efficiency and efficiency defect. The method of exergy provides a measure to judge the magnitude of energy waste in relation to the energy supplied or transformed in the total plant and in the component being analyzed, a measure for the quality (or usefulness) of energy from the thermodynamic viewpoint and a variable to define rational efficiencies for energy systems.

Mahmoud Ghodbane[5] describes simulated performance of R152a and hydrocarbon refrigerants and their potential as alternative refrigerants to HFC-134a in mobile air conditioning systems. In addition, a comparative assessment of the performance of a secondary loop system using these refrigerants is provided. The secondary loop system delivers the same performance and comfort (i.e. cooling capacity) as the R134a baseline system with a small increase in energy usage. Depending on the ambient and driving conditions (i.e. road load and idle), the secondary loop system COPs with R152a as a primary refrigerant and 50/50 ethylene / water mixture as a secondary refrigerant are lower than the baseline by 5 to 12 %.

Dr Matthew Bryson[6] focused on developing experience and gaining data with the most likely synthetic drop-in replacement candidates, R152a and HFO-1234yf. The testing regime involved both laboratory “bench testing”, in a purpose-designed laboratory test bed, and also in-car testing. Both the bench and in-car testing were initially performed using the current industry standard mobile air conditioning refrigerant (R134a) to ascertain a base level of performance of the systems. Both of the replacement refrigerants had COPs and cooling capacities similar to R134a, with R152 having slightly higher values and HFO-1234yf slightly lower.

R S Mishra[7] Detailed energy and exergy analysis of multi-evaporators at different temperatures with single compressor and single expansion valve using liquid vapor heat exchanger vapor compression refrigeration systems have been done in terms of performance parameter for R507a, R125, R134a, R290, R600, R600a, R1234ze, R1234yf, R410a, R407c, R707, R404a and R152a refrigerants. The numerical computations have been carried out for both systems. It was observed that first law and second law efficiency improved by 20% using liquid vapor heat exchanger in the vapor compression refrigeration systems. It was also observed that performance of both systems using R717 is higher but R600 and R152a nearly matching same values under the accuracy of 5% can be used in the above system .

D.Sendil Kumar, Dr.R.Elansezhian[8] In this paper an experimental investigation was made to reduce the usage of HFC 134a with the Hydrocarbon Refrigerant mixtures (HCM) of R134a and R152a refrigerants in the proportion of 30:70, 50:50, and 70:30 by mass. Experiments were conducted by continuous running tests under an ambient temperature of 32°C. The overall performance of the system proved that the HCM could be a long term alternative for R134a.

Jitendra Kumar Verma[9] A refrigerant is a substance used in a heat cycle usually for enhancing efficiency, by a reversible phase transition from a liquid to a gas. Traditionally, fluorocarbons, especially chlorofluorocarbons, were used as refrigerants, but they are being phased out because of their ozone depletion effects. Other common refrigerants used in various applications are ammonia, sulfur dioxide, and non-halogenated hydrocarbons such as propane. R134a is an inert gas used primarily as a “high-temperature” refrigerant for domestic refrigeration and automobile air conditioners. Contact of R134a with flames or hot surfaces have toxic and hazardous effect on the humans and environment.

Sandip P. Chavhan[10] various obstacles faced in working of different refrigerants due to their environmental impact (R11, R12), toxicity (NH3), flammability (HC) and high pressure (CO2); which makes them more hazardous than other working fluids according to safety and environmental issues. We observed the performance of different environmental friendly refrigerants and their mixtures in different proportions. We also observed the effect of working parameters like dimensions of capillary tube, working pressures and working temperatures, which affect the coefficient of performance (COP) of vapour compression refrigeration system.

A.Baskaran[11] performance analysis on a vapor compression refrigeration system with various eco-friendly refrigerants of HFC152a, HFC32, HC290, HC1270, HC600a and RE170 were done and their results were compared with R134a as possible alternative replacement. The results showed that the alternative refrigerants investigated in the analysis RE170, R152a and R600a have a slightly higher performance coefficient (COP) than R134a for the condensation temperature of 50° C and evaporating temperatures ranging between -30° C and 10° C.Refrigerant RE170 instead of R134a was found to be a replacement refrigerant among other alternatives. The effects of the main parameters of performance analysis such as refrigerant type, degree of sub cooling and super heating on the refrigerating effect, coefficient of performance and volumetric refrigeration capacity were also investigated for various evaporating temperatures.

Ali Kilicarslan[12] Water as a refrigerant (R718) is compared with some current natural (R717 and R290) and synthetic refrigerants (R134a, R12, R22, and R152a) regarding environmental issues including ozone depletion potential (ODP) and global warming potential (GWP), safety (toxicity and flammability), operating cost, refrigeration capacity and coefficient of performance (COP). A computer code simulating a simple vapour compression cycle was developed to calculate COPs, pressure ratios, outlet temperatures of the refrigerants from the compressor, and evaporator temperatures above which water theoretically yields better COPs than the other refrigerants investigated.

Bukola O. Bolaji[13] The effects of evaporator temperature on the coefficient of performance (COP), exergy flow destruction, exergetic efficiency and efficiency defect in the four major components of the cycle for R12, R134a and R152a were experimentally investigated. The results obtained showed that the average COP of R152a was very close to that of R12 with only 1.4% reduction, while 18.2% reduction was obtained for R134a in comparison with that of R12. The highest average exergetic efficiency of the system (41.5%) was obtained using R152a at evaporator temperature of -3.0oC.

S.Vandaarkuzhali[14] evaluated R152a, hydrocarbon candidates and their potential as a replacement for R134a in mobile air conditioning systems. The performances of R152a in comparison with R22 are presented, from the theoretical as well as from an experimental point of view. The influence of R152a on compressor reliability has been also evaluated analyzing the bearing load and considering both the materials compatibility and the oil solubility; the lower operating temperature has a positive impact on compressor reliability. Some considerations of safety and why we are choosing R152a for our research are also presented.

III. REFRIGERANT PROPERTIES

Refrigerant properties are necessary to describe the operating characteristics of the refrigerant within a system. In particular, physical properties of refrigerants are useful for determining the applicability of a refrigerant under design operating conditions. Thermodynamic and transport properties of refrigerants are necessary for predicting system behavior and performance of components. Basic properties are provided in Table for more comprehensive data the refrigerant supplier or reference texts should be consulted.

Table-1 Physical, safety and Environmental Properties of HFC152a [5]

Properties	**HFC152a**	**HFC134a**
Chemical Formula	CH3CHF2	CH2FCF3
Molecular Mass	66.05	102.03
Critical Temperature (°F)	235.90	214.00
Critical Pressure (psia)	656.00	589.00
Normal Boiling Point (°F)	-11.20	-15.00
Lubricant	N/A	POE/PAG
Stability	Stable	Stable
OSHA Permissible Exposure Limit (ppm)	1000	1000
Lower Flammability (% Volume in Air)	4.80	None
Heat of Combustion (Btu/lbm)	7481	1806
Safety Group	A2	A1
Auto Ignition Temperature (°F)	851	1418
Atmospheric Life (yr.)	2	14
Ozone Depletion Potential	0	0
Global Warming Potential (100 yr.)	120	1430

Need for Alternatives of R134A

Since 2010 to onwards be the fourth generation is being focusing on refrigerants that do not contribute to global warming, ozone layer depletion, efficient, non flammable and non toxic with good stability. But the outlook for discovery or synthesis of these ideal refrigerants is extremely unlikely. Therefore, trade-off among desired objectives is necessary to achieve the balanced solution [9].

Montreal Protocol The United Nations environment programme conference held in Montreal in September 1987 the decision taken to phase out ozone depleting substances (ODS) within a fixed time period is known as Montreal Protocol. Some of the feature of MP is as follows[9].

1) Developed countries will phase out CFCs by 1996.
2) Developing countries will phase out CFCs by 2010 with freeze in 1999 and gradual reduction thereafter. Developed countries will phase out HCFCs by 2030 while developing countries have been provided a grace period of ten years i.e. phase out by 2040.
3) Global warming is another serious issue. Some naturally occurring substances mainly cause this but CFCs have very large global warming potential.

Kyoto Protocol Kyoto protocol aims at phasing out of substances that will lead to global warming. And R134a is used in domestic refrigerator and other vapour compression systems as it was identified as a replacement to CFC-12, keeping in view its zero ozone depleting potential. R134a has 1300 global warming potential per 100 year, which is very high. The sale of R134a reported to AFEAS 1970-2003 [21] is significantly increasing during the past two decades. The increased emission of R134a to the atmosphere are steadily increasing the concentration of green house gases via leaks and mostly, in an indirect way, via energetic performance of refrigeration plant. This will lead to adverse climatic problem. Hence, R134a is one of the six chemicals in the ―basket‖ that are to be phased out in the near future under Kyoto protocol[9].

Environmental concern

There are two major concern of environmental concern.
1) 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[9].
2) 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 CO2 as the bench mark i.e. CO2 is assigned a value and other components are compared to CO2[9].

Results from Literature survey

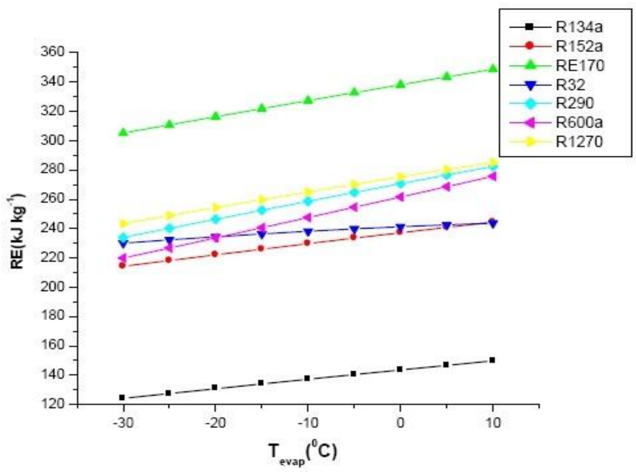

Fig.3. Refrigerating effect Vs evaporating temperature[11]

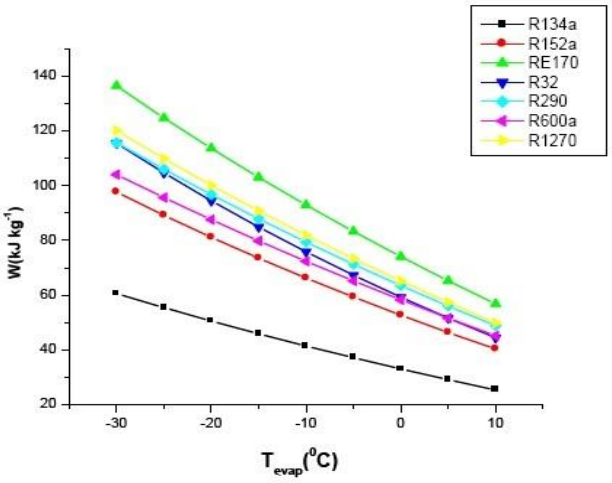

Fig. 4.Compression Work Vs evaporating temperature[11]

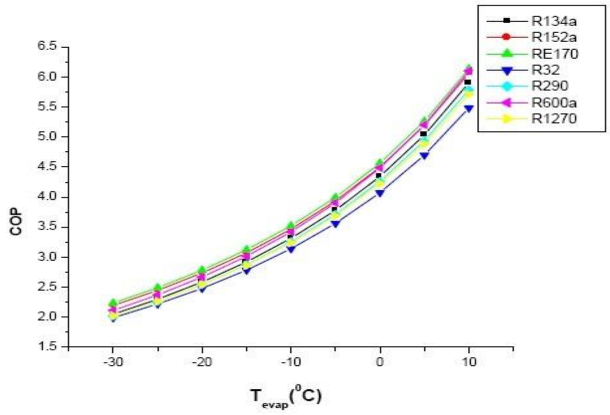

Fig.5. Coeffiecient of performance Vs Evaporation temperature[11]

IV. CONCLUSION

From the literature survey it is clear that refrigerant R134a is having higher global worming potential (GDP) than R152a and it can be concluded that, refrigerant R152a have slightly higher COP, Cooling capacity, condenser capacity, energy efficiency than R134a. Hence considering above mentioned protocols and the results obtained from the experimental work refrigerant R152a is a good alternative for R134a.

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