Experimental Investigation on R 290 and R 600a In a Vapor Compression Refrigeration

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Abstract— **This investigation thermodynamically analyzes a vapour compression refrigeration system which compares R134a and R290/R600a refrigerants. The refrigerants like R12 and R22 contain chlorine atoms which are main reasons for the emission of Chlorofluorocarbon which is responsible for the ozone depletion. Hence, the alternate refrigerants like R-134a and hydrocarbon mixture (R290/R600a) are used to avoid emission of CFC. These refrigerants have zero ozone depletion potential and negligible global warming potential. The COP of the system was improved by replacing the R134a with blended Hydrocarbon R290/R600a refrigerant. In this paper, the experimental analysis of R134a and various ratios of R290/R600a refrigerants have been analyzed. In the present work performance comparison between R-134a and hydrocarbon mixture (R290/R600a) has been carried out in domestic refrigerator. Generally, the overall performance of the applied mixtures was much better than that of R134a.**

Keywords- Vapor compression refrigeration, R290/R600a, ozone depletion potential, COP

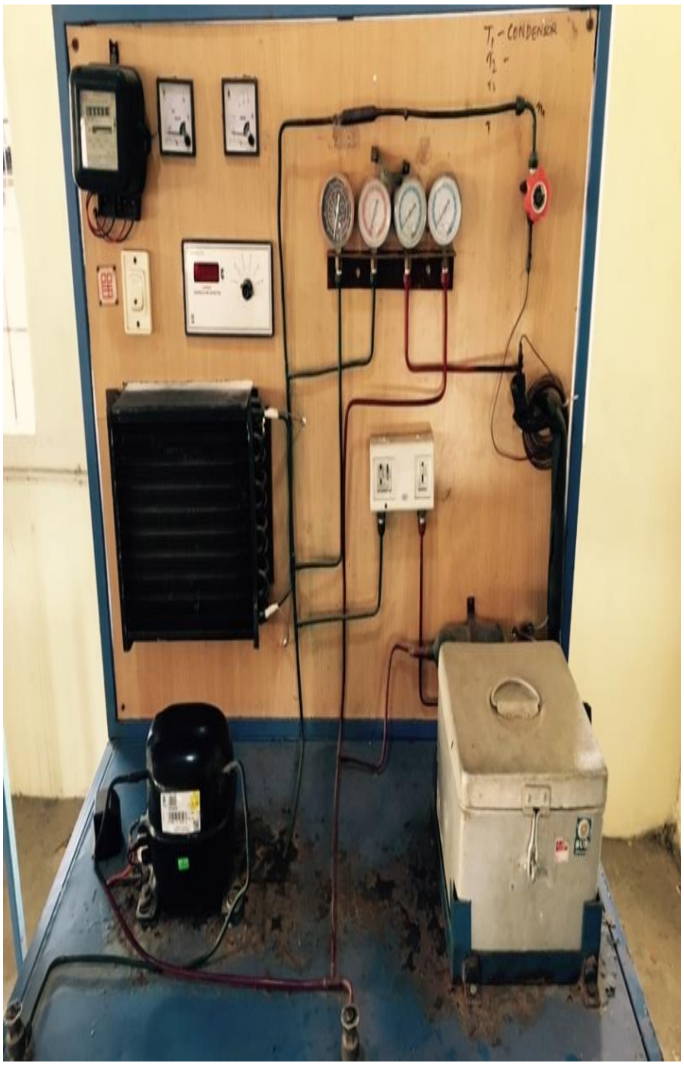
I. INTRODUCTION

Refrigeration is the combination of mechanical equipment wherein a refrigerant is circulated for cooling or extracting heat from spaces or bodies. One of the most important applications of refrigeration has been the prevention of perishable food products by storing them at low temperatures.

The most commonly used refrigeration system in refrigerators is vapour compression refrigeration system. The working fluid mentioned in the system is in the state of liquid and vapour. The ability of certain liquids to absorb enormous quantities of heat as they vaporize is the basis of this system. Chlorofluorocarbons (CFCs) have been used extensively for the past few decades due to their excellent thermodynamic properties and chemical stability. In particular CFC12 has been predominantly used for small refrigeration units including domestic refrigerator/freezers. CFCs have been stopped because of their effects on stratosphere ozone and their potential contribution to global warming; CFCs are now controlled substance by the Montreal protocol [2]. Hydrofluorocarbon-134a, have been used to replace CFC12 used in refrigeration and air conditioning. HFC 134a has got zero ozone depleting potential (ODP) whereas it is found to be not easily miscible with the conventional mineral oil used as lubricant in refrigerators [3]. It has the good characteristics of zero ODP, non-flammability, stability, and has a close match to R12. The R134a has zero ODP but it has relatively high global warming potential. Hence there is a need to identify alternative refrigerant for replacement of R134a. On more investigation experimentally use of hydrocarbon refrigerant mixture R290 and R600a are used as an alternative refrigerant to R134a in domestic refrigerator [4]. The performance of hydrocarbon such as propane (R290) and isobutene (600a) had similar performance as that of R134a and analyzed in the vapour compression refrigeration system. The hydrocarbon (R600a) as refrigerant have several good characteristics such as zero ozone depletion potential, very low global warming potential, low toxicity, miscibility with lubricant, good compatibility with the materials usually employed in refrigerating system. It also has characteristics of high cooling performance, low power consumption, load temperature rising speed is slow and has various compactible lubricants. The main drawback of using hydrocarbons as refrigerant was due to their flammability. Various safety measures have been developed in handling flammability and safety problems such as using enhanced compact heat exchangers, optimizing system designs, reducing the charge of systems and establishing rules and regulations for safety precautions. Therefore, in this study, the performance of R134a and R290/R600a refrigerants in a vapour compression refrigeration system is conducted by experimental analysis of performance parameters. Also, the results obtained were compared to each other.

II. EXPERIMENTAL SETUP

For carrying out this investigation and experimental work, refrigeration test rig was works on Vapour compression cycle. This experimental set up was designed to find out the COP of the domestic vapour compression system. The Refrigeration test rig consists of a compressor, Forced convection air cooled condenser, Expansion valve (Capillary tube) and an evaporator (Shell and coil type). The compressor used here is a hermetically sealed reciprocating compressor. A serpentine coil finned tub e air cooled heat exchanger is used as condenser and is made up of copper. Condenser is cooled using fan. The evaporator is in the type of cylindrical spiral coil shape and made up of the copper. Separate pressure gauges are provided to measure the suction and discharge pressures. The Digital temperature indicators are used to measure the various temperatures at various locations such as condenser inlet (T1), condenser outlet (T2), evaporator inlet (T3) and evaporator outlet (T4). Energy meter is used to measure the power consumption of the compressor. For carrying out the testing of the Refrigeration test rig, the refrigerant R134a was charged into the test rig and trial was conducted. Then test rig was properly evacuated using vacuum pump, and blend of refrigerant R290 and R600a was charged for conducting the trial and the readings are tabulated. Calculate the coefficient of performance & energy consumption for vapours compression refrigeration system. And the



experiment is repeated for refrigerant (R-134a and R290/R600a) and the readings are measured.

Figure (1) Experimental Setup

.Table (1) Properties of Refrigerant

Properties of refrigerant	Molecular weight (g)	Boling point(° C)	Melting point (° C)	Flammability limit in air	Ozone depletion potential (ODP)	Global warming potential (GWP)
R 134 a	102.03	-26.1	-103.3	None	0	1300
R 600 a	58.1	-11.6	-159.42	Flammable	0	0.0011

III. RESULTS AND DISCUSSION

A. *COP VS EVAPORATOR TEMPERATURE*

Comparisons of the COP for R290 and R600a mixtures with R134a, as a function of evaporating temperatures are shown in Figures 2. Similar trends were observed in the two figures, for all the refrigerants considered, COP increases with an increase in evaporating temperature. The COP of the hydrocarbon mixtures is higher than that of R134a. Again, the highest COP was obtained.

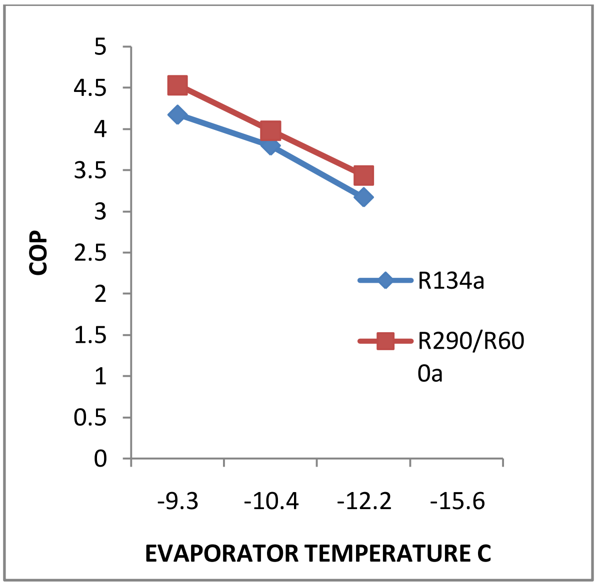


Figure 2: variation of cop vs. evaporator temperature

B. *POWER CONSUMPTION VS EVAPORATOR TEMPERATURE*

From the graph and results it was founded that power consumption of compressor get reduced when we used R600a for comparing the R-134a as a refrigerant. Also when we use the blend of R290 and R600a as a refrigerant compressor temperature was lower than the R-134a as a refrigerant

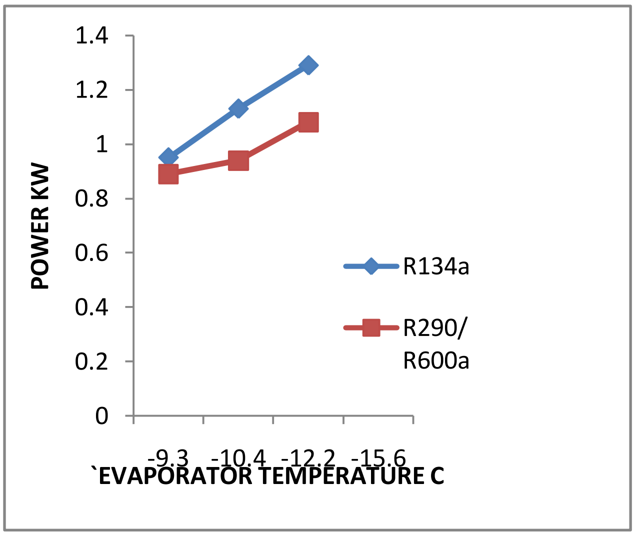


Figure 3: Variation of power consumption vs. evaporator temperature

C. COMPRESSOR WORKDONE VS EVAPORATOR TEMPERATURE

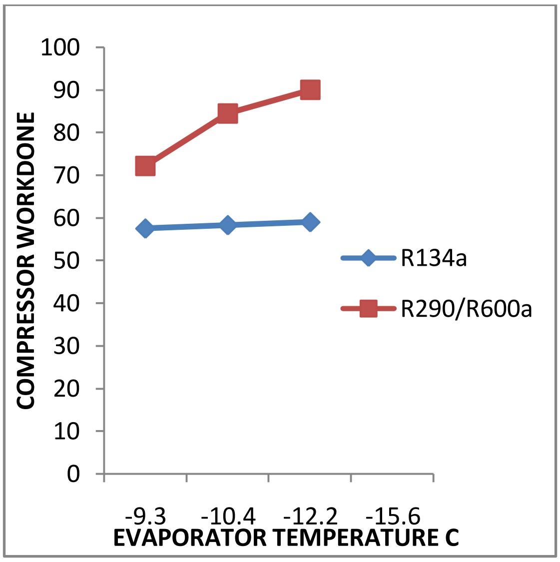


Figure 4: compressor work done vs. evaporator temperature

The variation of compressor work with evaporating temperature is shown in Figure 4. The figure shows that the work of compression decreases as the temperature of the evaporator increases. This is due to the fact that when the temperature of the evaporator increases, the suction temperature also increases. At high suction temperatures, the vaporizing pressure is high and, therefore, the density of the suction vapour entering the compressor is high. Hence, the mass of refrigerant circulated through the compressor per unit time increases with the increase in suction temperature for a given piston displacement. The increase in the mass of refrigerant circulated decreases the work of compression. The works of compression using mixtures of R290 and R600a are higher than that of R134a, but they also exhibited much higher refrigerating effects than those of R134a. The lowest compressor work was obtained.

D. COP VS TIME (MINUTES)

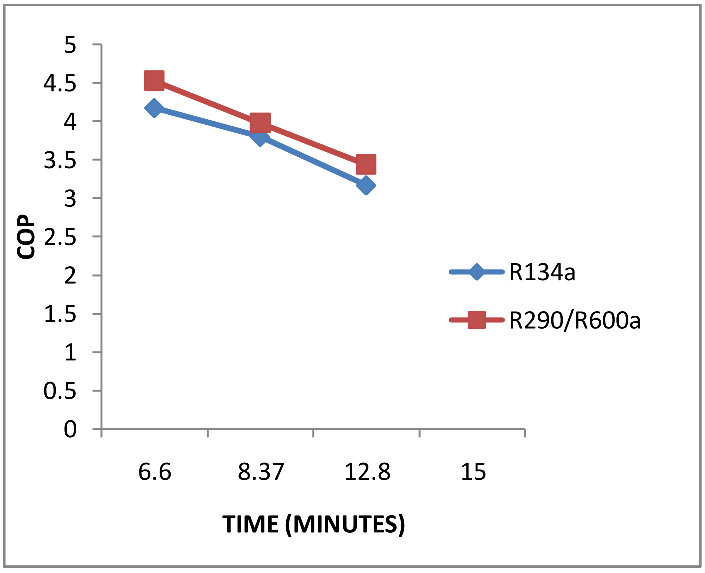


Figure 5: Variation of cop vs. time

The Variation of COP with time in Full loading condition. The pressure and temperature at the suction and discharge of the compressor and that of condenser are measured under loading condition by Switching ON the refrigerator. COP increases with increase in time due to suction pressure and temperature increases in the compressor. Therefore, work done in the compressor increases

E. REFRIGERATION EFFECT VS EVAPORATOR TEMPERATURE

Above figure shows the variation of the refrigerating effect with evaporating temperature. As shown in the figure, the higher the percentage of R600a in the mixture, the lower the refrigerating effect of the mixture. The refrigerating effect increases with an increase in evaporating temperature, which is due to the increase in the latent heat value of the refrigerant. A very high latent heat value is applicable, since the mass flow rate per unit of capacity is less. When the latent heat 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, more Compact pieces of equipment. It is clearly shown that the hydrocarbon mixtures exhibited higher refrigerating effects than R134a. Therefore, a very low mass of refrigerant would be required for the same capacity, and a smaller compressor size would also be required, due to their high latent heat values.

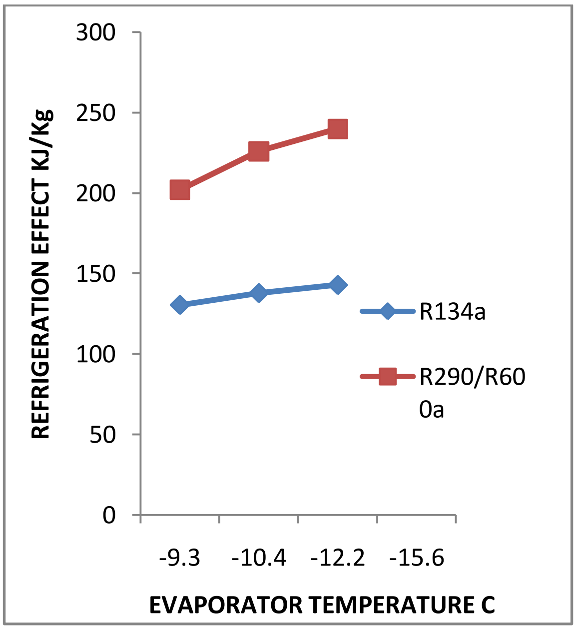


Figure 6: Variation of refrigeration effect vs evaporator temperature

IV. CONCLUSION

The following points were drawn from this experimental investigation

- From this Experiment, the Coefficient of Performance of the Blended Hydrocarbon R290/R600a mixtures is high when compared with the R134a refrigerant.
- The Power consumption of the Hydrocarbon refrigerant R290/R600a has been decreased as compared to the R134a.
- The coefficient of performance has increases while time increases due to suction of high pressure and temperature increases.
- The Compressor work has been increased by using the mixture of R290/R600a hydrocarbon than that of R134a.
- Hydrocarbon R290/R600a mixture has higher refrigerant effects than R134a due to higher latent heat values.
- R134a has higher GWP. Hence permanent solution is necessary. (R290/R600a) with zero ODP and negligible GWP. Hence R600a has been be used as an alternative refrigerant.

ACKNOWLEDGMENT

The author would like to thank the Correspondent Rev Sister Arockia Mary, Principal Dr Sujatha Jamuna Anand Vice Principal Dr R.D Samuel and Head Of the Department Mechanical engineering Mr Nimal Swarna Ross of Loyola institute of technology Chennai for their kind support and encouragement to carry out this project work

REFERENCES

[1]. G. MaruthiPrasad Yadav, P. RajendraPrasad , G. Veeresh, “Experimental analysis of vapour compression refrigeration system with liquid line suction line heat exchanger by using R134a and R404a”, *International Journal of Scientific research and management studies* vol.1 Issue 12, pg:382-395.

[2]. Jagnarayan Rawani, Satyendra Kumar Prasad, Jitendra Nath Mahto “Performance Analysis of Mixtures of R290 and R600a With Respect To R134a in Simple Vapour Compression Refrigeration System”, *International journal of innovative research in science, engineering and technology*, vol 5, Issue 6, 2016.

[3]. Murat Hozod, “Performance comparison of Single stage and Cascade Refrigeration systems using R134a as the working fluid”, *Turkish J.Eng.* Sci vol 29, 285-269.

[4]. Mohanraj.M , Jayaraj.S , Muraleedharan.C and Chandrasekar.P (2009) “Experimental investigation of R290/R600a mixture as an alternative to R-134a in a domestic refrigerator*”, International Journal of Thermal Sciences* Vol.48,pp.1036–1042.

[5]. Richardson, R.N., Butterworth, J.S., “The performance of propane/isobutene mixtures in a vapour compression refrigeration system”. *International Journal of Refrigeration*, vol 18, pp.1, 58-62, 1995.

[6]. Maclaine-Cross, I.L., “Why hydrocarbons save energy”. *AIRAH Journal* vol.51, pp. 33- 37, 1997.

[7]. Kim, M.H., Lim, B.H., Chu, E.S., “The performance analysis of a hydrocarbon refrigerant R-600a in a household refrigerator/freezer”. *KSME International Journal*, Vol.12, No.4, pp.753-760. 1998.

[8]. Sopan R. Arote and D. D. Palande, **“**Comparative performance analysis of vapour compression refrigeration system with R134a and the blend of hydrocarbon R290/R600a*”, Global Journal of Engineering science and Research, Arote* 2[12], Dec 2015

.

[9]. M.Abuzar Qureshi, Shikha Bhatt, Comparative Analysis of Cop Using R134a & R600a Refrigerant in Domestic Refrigerator at Steady State Condition, *International Journal of Science and Research*, ISSN (Online): 2319-7064**.**

[10]. Kadam Sanjay V., Sutar S.S., Retrofitting of refrigeration Bench Test Rig - Replacing R-12 refrigerant by R134a refrigerant, *IOSR Journal of Engineering*, May.2012, vol 2(5), pp:952-955.

[11]. K. Nagalakshmi, G. Marurhiprasad Yadav., The Design and Performance Analysis of Refrigeration System Using R12 & R134a Refrigerants, *International Journal of Engineering Research and Applications, February 2014, pp.638-643.*

[12]. B.O. Bolaji1, M.A. Akintunde2, and T.O. Falade3. Comparative Analysis of Performance of Three Ozone-Friends HFC Refrigerants in a Vapour Compression Refrigerator, *Journal of Sustainable Energy & Environment 2 (2011) 61-64*

[13]. Akintunde, M.A., Experimental Study of R134a, R406A and R600a Blends as Alternative to Freon 12, *The Federal University of Technology* e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 7, Issue1 (May. - Jun. 2013), *PP 40-46.*

[14]. 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)*

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