Performance Analysis of Vapors Compression Refrigeration System with Hydrocarbon Blend Mixture of Different Refrigerants

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Abstract **- Millions of refrigeration system is domestic refrigerator & air conditionings operating with R134a in whole world have to retrofit suitably in the event of the phase out because of higher (GWP) global warming potential like, 1400.HC mixture is an substitute refrigerant of hydro fluorocarbon (HFC) and chlorofluorocarbon (CFC) compound due to their low global warming potential and zero ozone depletion potential, the effect on the environment is also reduce due to uses of hydrocarbon mixture in different mass ratio . Refrigerant have been experimental performance analysis of the refrigeration system. used such as R134a & R1270, R290 and CARE-30(Blend Mixture of R600a & R290). Few researcher has been prove that the refrigerant R134a, Hydrocarbon Blend Mixture R600a&R1270 (90%+10%), Hydrocarbon Blend Mixture R600a&R1270 (80%+20%) & CARE30 (R1270 (50%) +R290 (50%)) used in hermetically sealed compressor by using REFPROF software which define the property of the refrigerant and blend mixture of refrigerant. We are going to experimentally analysis with the help of U-RIG TEST (SVCR) for the mixture of following hydro fluorocarbon (HFC) & Hydrocarbon (HC) Refrigerant.**

1. **R134a**
2. **Hydrocarbon Blend Mixture R600a&R1270 (90%+10%)**
3. **Hydrocarbon Blend Mixture R600a&R1270 (80%+20%)**
4. **CARE-30 (R600a (50%) &R290 (50%))**

Many performance measure like pressure ratio, compressor discharge temperature, volumetric efficiency, and volumetric cooling capacity mass flow rate are examined, the performance in term of refrigerating capacity, coefficient of performance (COP) and compressor work to evaluated for the investigating refrigerant at various condensing temperature & evaporating temperature .

CARE-30 has been found that as a new refrigerant (R600a/R290)(50/50by wt.%) blend has better performance & improved the COP of the system. It have higher than R134a, Hydrocarbon Blend Mixture R600a&R1270 (90%+10%), Hydrocarbon Blend Mixture R600a&R1270 (80%+20%),The results of the present investigation have proved that the new alternative refrigerant CARE-30 could be a better substitute.

Index Terms **-Refrigerant, R134a, R600a, R1270, R290, ODP, GWP, U-RIG TEST.**

I. INTRODUCTION

Worldwide attempts are being made to phase out the production and consumption of Hydro Chloro Fluorocarbon (HCFCs) and Chlorofluorocarbon CFCs), as these chemicals are responsible for depletion of stratospheric ozone layer. Refrigeration, Air conditioning and heat pumps sectors are one of the principal users of these chemicals. As per Montreal Protocol (1987), refrigerant R22, the generally accepted and most suitable refrigerant for air conditioners must be phased out by 2030 by developed countries and by 2040 by developing countries because of its Ozone Depleting Potential. The phasing out of ozone depleting refrigerants has led to the quest for eco-friendly alternative refrigerants and substitutes for R22 have been developed. Since the demand for air conditioners by the people are increasing throughout the world day by day, considering the indirect Global Warming and Ozone Depletion, it is an urgent need to improve the energy efficiency of vapor compression system as it is most widely used in majority of modern cooling equipments.[1]

Refrigeration and air-conditioning system plays an important role in modern life. They not only provide comfortable and healthy living environments, but have also come to be regarded as necessities for surviving severe weather and preserving food. Unfortunately, accelerated technical development and economic growth throughout the world during the last century have produced severed environmental problems, forcing us to acknowledge that though these technological advances may contribute to human comfort, they also can threaten the environment through ozone depletion (ODP) and global warming Potential (GWP). The linkage of the CFC refrigerants to the destruction of the ozone layer, which has been established recently, is attributable to their exceptional stability because of which they can survive in the atmosphere for decades, ultimately diffusing to the rarefied heights where the stratospheric ozone layer resides. The inventors of these refrigerants could not have visualized the ravaging effects of the refrigerants on the ozone layer. This paper analyses the processes of selecting environment friendly halocarbon refrigerants that have zero ODP, non-flammable, non-toxic and low GWP. It also examines and discusses the current available alternative refrigerants in vapour compression refrigeration system [2]

Refrigeration is used in industry for cooling and freezing of products, condensing vapors, maintaining environmental conditions, and for cold storage. The number of different applications is huge and they are a major consumer of electricity. In some sectors, particularly food, drink, and chemicals it represents a significant proportion of overall site energy costs as per must follow these formatting specifications exactly. Presently the refrigeration industry urgently needs technical information on the refrigeration systems, system components, and technical and operational aspects of such systems and components, procedures for energy and energy analyses of refrigeration systems for system design and optimization, application of optimum refrigeration techniques, techniques for the measurement and evaluation of the components' performance; and methodology for the use of the cooling data to design an efficient and effective refrigeration system and/or to improve the existing refrigeration systems.[3]

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 . 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. 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 . 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. [4]

II. EXPERIMENTAL SET UP

The performance study includes measurement of temperature, pressure values at various places in the VCR system viz., compressor inlet, outlet and evaporator inlet and outlet in accordance with the performance calculation. The vapor compression system is initially cleaned by nitriding the entire system and the evacuation of the system is carried out with the help of a vacuum pump for nearly 30 min and then the refrigerant is charged with the help of the charging system. The pressure and temperature values at various points of the setup were noted down at various time intervals.

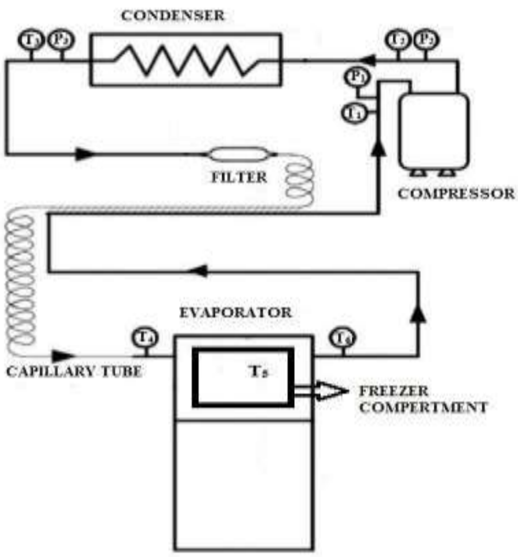


Figure 1 Schematic Diagram of a Domestic Refrigerator

- T1- Compressor Inlet Temperature
- T2-Compressor Outlet Temperature
- T3-Condenser Outlet Temperature
- T4-Evaporator Temperature

- P1-Compressor Inlet Pressure
- P2-Compressor Outlet Pressure
- h= Enthalpy (J/Kg).
- h_{f3}=Sensible heat of the condensate.

The various refrigerants that were used in the experimental setup are listed as.

1. R134a
2. Hydrocarbon Blend Mixture R600a&R1270 (90%+10%)
3. Hydrocarbon Blend Mixture R600a&R1270 (80%+20%)
4. CARE-30 (R600a (50%) &R290 (50%))

III. CALCULATION- FORMULA USED IN CALCULATION

- Power P =(V×I×COSØ) J/s and Mr = P/ (h_2-h_1) gm/s
- Refrigerating Effect, R.E = Mr (h_1-h_{f3}) J/s
- Work done, W.D = Mr (h_2-h_1) J/s
- Coefficient Of Performance, COP = RE/ WD

Calculation for R-134a refrigerant

Table 1 Observation for R-134a refrigerant

PARAMETER	NO LOAD	LOAD I	LOAD II	LOAD III
T_1 (°C)	-1.0	-0.6	-0.3	-0.2
T_2 (°C)	67	69	71.2	73
T_3 (°C)	52.3	54	55.2	56.3
T_4 (°C)	-10.1	-9.1	-8.9	-7.3
h_1 (KJ/kg)	397.51	398.25	398.20	399.26
h_2 (KJ/kg)	428.25	428.89	429.10	429.23
h_{f3} (KJ/kg)	274.71	277.86	281.04	282.02
h_4 (KJ/kg)	186.78	189.40	189.56	294.55
V (volt)	230	230	230	232
I (ampere)	0.90	0.90	0.90	0.90
P_d (bar)	11.2	11.2	11.4	11.6
P_s (bar)	0.35	0.42	0.42	0.42

Table 2 Result for R-134a refrigerant

S No.	LOAD	P(J/sec)	m_r(gm/sec)	R.E(J/sec)	WD	COP	T_4(°C)	T_3(°C)
1	NO	171.81	5.589	686.32	171.80	3.99	-10.1	52.3
2	I	171.81	5.607	675.02J	171.79	3.93	-9.1	54
3	II	171.81	5.56	651.40	171.80	3.79	-8.9	55.2
4	III	173.81	5.78	173.22	173.22	3.94	-7.3	56.3

Calculation for Hydrocarbon Blend Mixture R600a&R1270 (90%+10%) refrigerant

Table 3 Observations for Hydrocarbon Blend Mixture R600a&R1270 (90%+10%)

PARAMETER	NO LOAD	LOAD I	LOAD II	LOAD III
T_1 (°C)	-1.2	-1.0	-0.9	-0.6
T_2 (°C)	60	64.1	68.0	71.0

T_3 (°C)	58.6	62.6	64.0	67
T_4 (°C)	-9.7	-9.4	-8.9	-8.7
h_1 (KJ/kg)	555.27	555.39	555.38	557.34
h_2 (KJ/kg)	631.66	636.15	640.5	643.57
h_{f3} (KJ/kg)	343.54	357.54	271.68	382.40
h_4 (KJ/kg)	177.86	178.28	179.45	180.16
V (Volt)	230	230	230	232
I (Ampere)	0.90	0.90	0.89	0.89
P_d (Bar)	11.2	11.4	11.5	11.4
P_s (Bar)	0.31	0.32	0.34	0.41

Table 4 Results for R600a&R1270 (90%+10%)

S No.	LOAD	P(J/sec)	m_r(gm/sec)	R.E(J/sec)	WD	COP	T_4(°C)	T_3(°C)
1	NO	171.81	2.24	474.27	171.11	2.77	-9.7	58.6
2	I	171.81	2.12	419.44	171.21	2.44	-9.4	62.6
3	II	169.90	1.99	564.56	169.38	3.33	-8.9	64.0
4	III	169.90	1.97	344.63	169.87	2.02	-8.7	67.0

Calculation for (Hydrocarbon Blend Mixture R600a&R1270 (80%+20%) refrigerant

Table 5 Observation for (Hydrocarbon Blend Mixture R600a&R1270 (80%+20%))

PARAMETER	NO LOAD	LOAD I	LOAD II	LOAD III
T_1 (°C)	-1.7	-1.5	-0.6	- 0.5
T_2 (°C)	49.5	55.9	60.9	64.1
T_3 (°C)	49	50.5	51	52.4
T_4 (°C)	-10	-9.3	-7.1	-5.8
h_1 (KJ/kg)	557.51	557.13	558.27	558.39
h_2 (KJ/kg)	618.55	625.53	630.70	633.86
h_{f3} (KJ/kg)	325.8	325.83	327.20	331.01
h_4 (KJ/kg)	546.41	547.28	570.07	551.72
V (Volt)	230	230	230	230
I (Ampere)	0.9	0.9	0.89	0.89
P_d (Bar)	11.2	11.4	11.5	11.4
P_s (Bar)	0.31	0.32	0.34	0.41

Table 6 Results for (R600a (80%) &R1270 (20%))

S No.	LOAD	P(J/sec)	m_r(gm/sec)	R.E(J/sec)	WD	COP	T_4(°C)	T_3(°C)
1	NO	171.81	2.81	642	171.51	3.74	-10	49
2	I	171.81	2.51	580.56	171.68	3.38	-9.3	50.5
3	II	169.90	2.34	540.70	169.48	3.19	-7.1	51
4	III	169.90	2.25	511.60	169.80	3.01	-5.8	52.4

Calculation for CARE-30 (R600a (50%) &R290 (50%))

Table 7 Observation for CARE-30 (R600a (50%) &R290 (50%)) refrigerant

PARAMETER	NO LOAD	LOAD I	LOAD II	LOAD III
T_1 (°C)	-1.8	-1.5	-0.7	-0.5
T_2 (°C)	49.2	55.1	61.1	64.3
T_3 (°C)	49.3	50.2	51.4	52.8
T_4 (°C)	-10.1	-9.2	-6.9	-5.9
h_1 (KJ/kg)	572.16	572 .13	574.39	5 74.32
h_2 (KJ/kg)	620.58	625.20	627.88	629.92
h_{f3} (KJ/kg)	331.81	337.92	337.92	352.50
h_4 (KJ/kg)	563.11	565.59	567.66	567.66
V (Volt)	230	230	230	232
I (Ampere)	0.9	0.9	0.89	0.89
P_d (Bar)	11.2	11.4	11.5	11.4
P_s (Bar)	0.31	0.32	0.34	0.41

Table 8 Results for CARE-30 (R600a (50%) &R290 (50%))

S No.	LOAD	P(J/sec)	m_r(gm/sec)	R.E(J/sec)	WD	COP	T_4(°C)	T_3(°C)
1	NO	171.81	3.54	850.839	171.80	4.95	-10.1	49.3
2	I	171.81	3.23	759.0823	171.41	4.428	-9.2	50.2
3	II	171.81	3.212	759.57	171.81	4.42	-6.9	51.4
4	III	173.304	3.11	689.86	173.303	4.01	-5.9	52.8

IV. RESULT AND DISCURSION

The experiment was conducted on a vapor compression system retrofitted with the four different refrigerants. Based on the recorded data the thermo physical properties with respect to effect of evaporator temperature, work of compression, evaporator load on refrigeration effect and mass flow rate, work of compression on actual COP were calculated and the results were graphically plotted as shown in Fig. (2-21).

No Load Graph

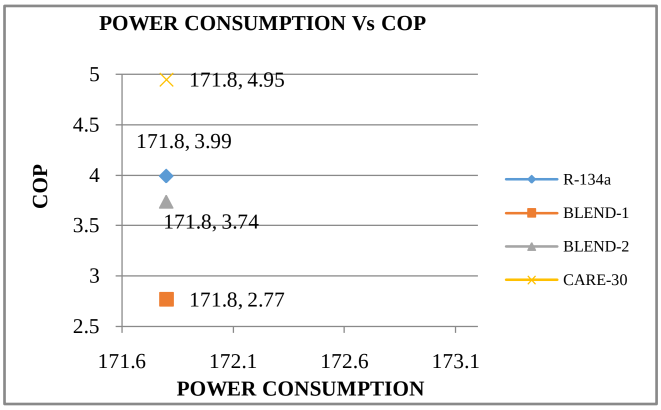


Figure 2 Variation of P.C vs. C.O.P

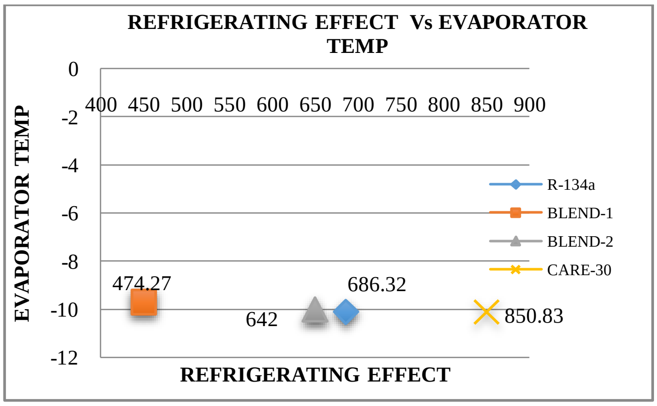


Figure 3 Variation of R.E vs. E.T

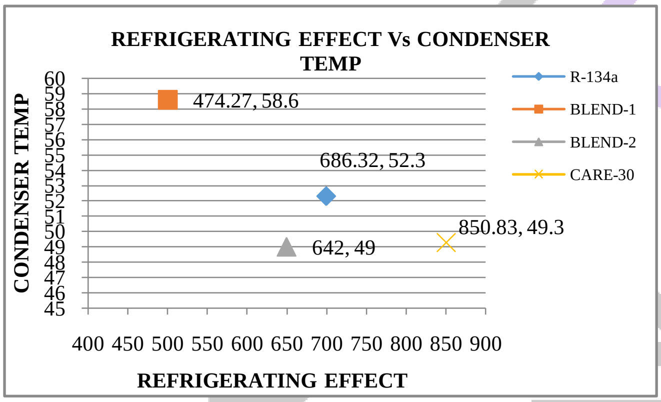


Figure 4 Variation of R.E vs. C.T

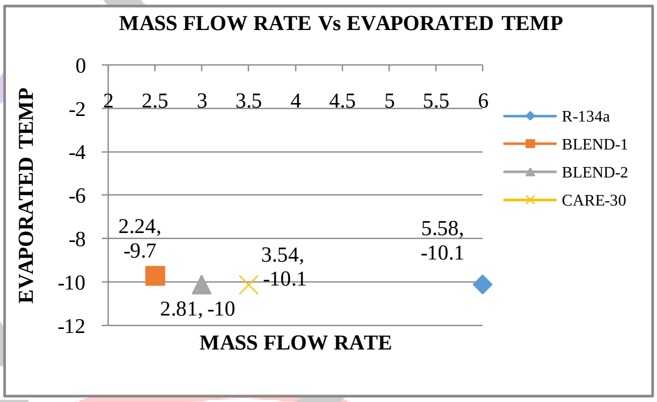


Figure 5 Variation of M.F.R vs.E.T

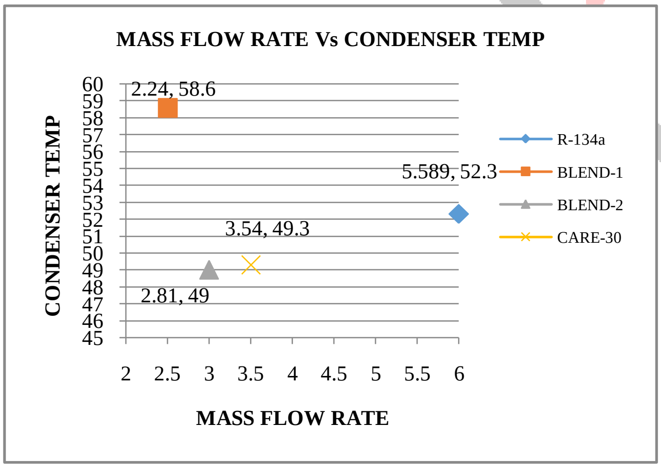
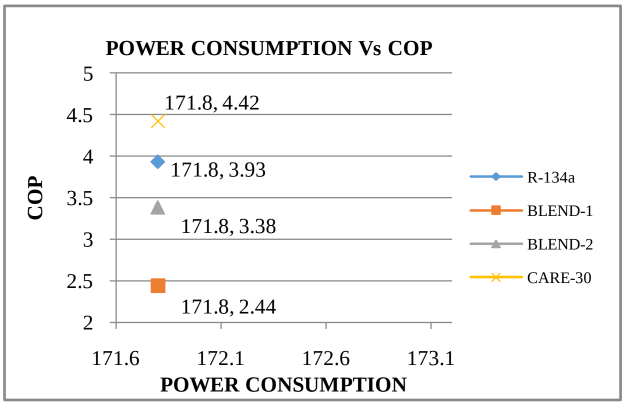


Figure 6 Variation of M.F.R vs. C.T

P.C - POWER CONSUMPTION
COP – COEFFICIENT OF PERFORMANCE
R.E - REFRIGERATING EFFECT
E.T - EVAPORATOR TEMPERATURE
C.T -CONDENSER TEMPERATURE
M.F.R - MASS FLOW RATE

Load-1 Graph



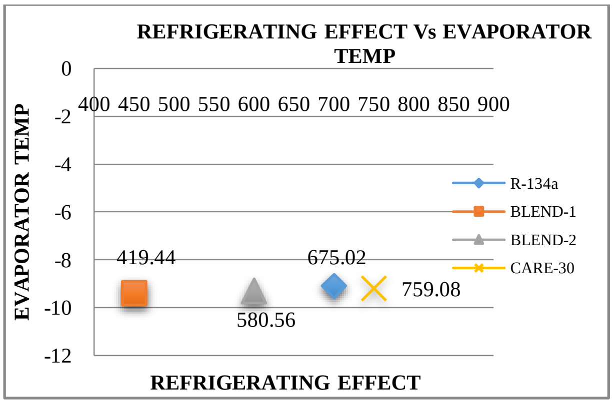
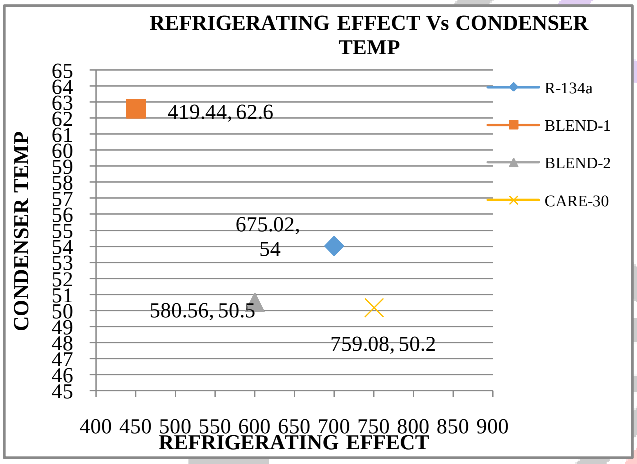


Figure 7 Variation of P.C vs. C.O.P

Figure 8 Variation of R.E vs. E.T



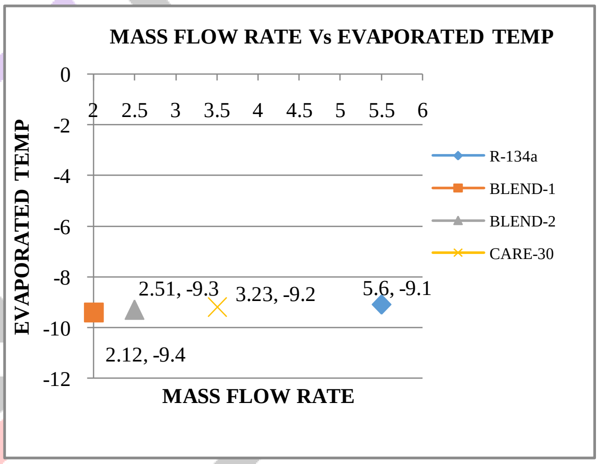
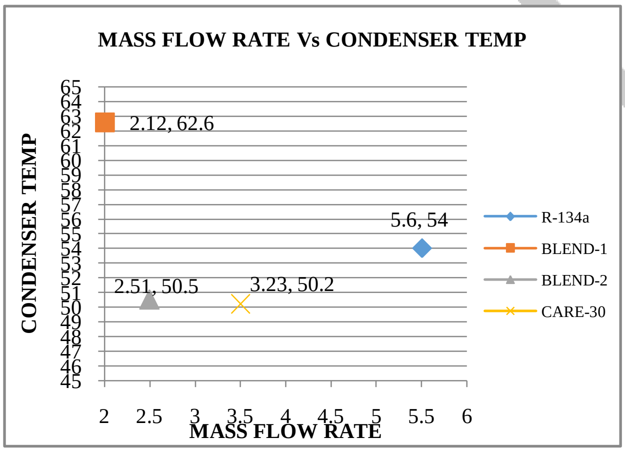


Figure 9 Variation of R.E vs. C.T

Figure 10 Variation of M.F.R vs.E.T



P.C - POWER CONSUMPTION
COP – COEFFICIENT OF PERFORMANCE
R.E - REFRIGERATING EFFECT
E.T - EVAPORATOR TEMPERATURE
C.T -CONDENSER TEMPERATURE
M.F.R - MASS FLOW RATE

Figure 11 Variation of M.F.R vs. C.T

Load-2 Graph

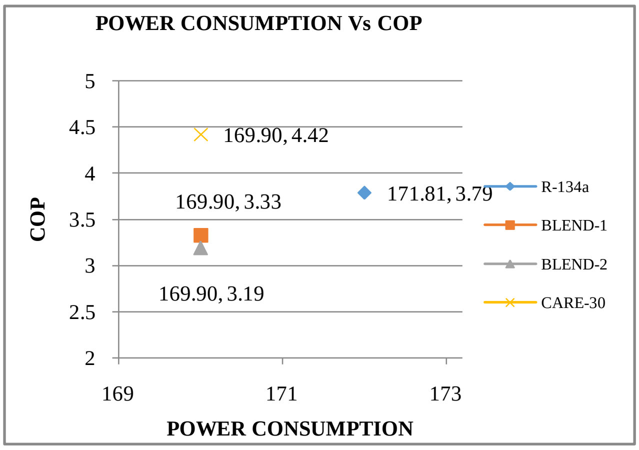


Figure 12 Variation of R.E vs. C.T

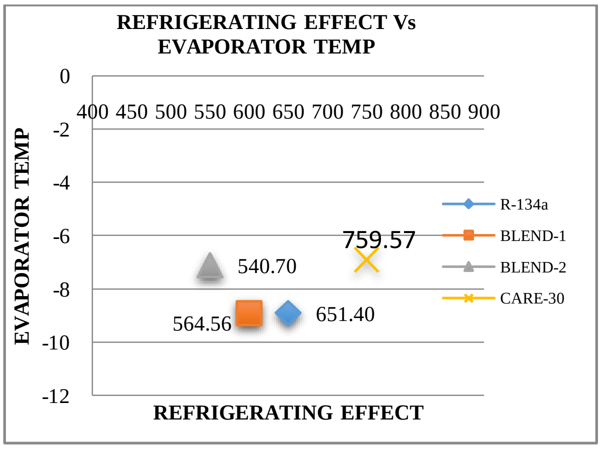


Figure 13 Variation of M.F.R vs.E.T

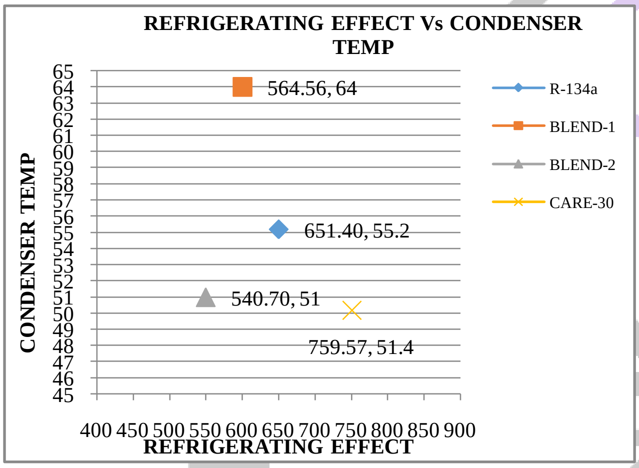


Figure 14 Variation of R.E vs. C.T

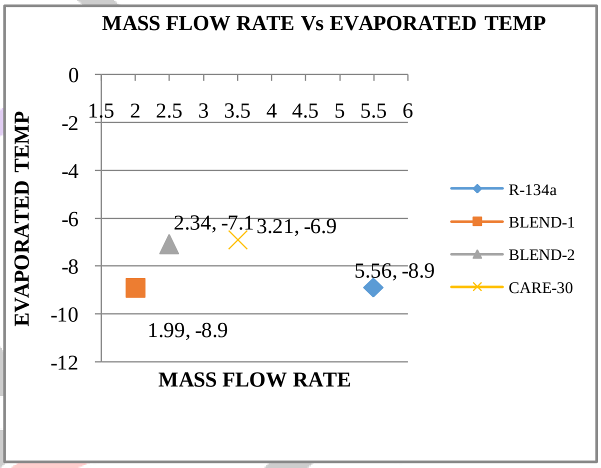


Figure 15 Variation of M.F.R vs. E.T

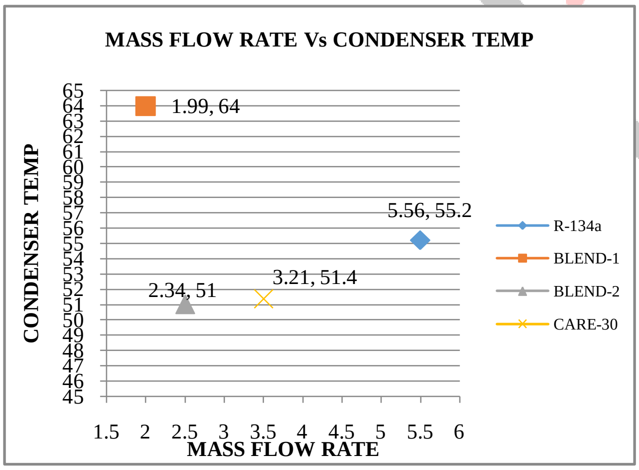


Figure 16 Variation of M.F.R vs. C.T

P.C - POWER CONSUMPTION
COP – COEFFICIENT OF PERFORMANCE
R.E - REFRIGERATING EFFECT
E.T - EVAPORATOR TEMPERATURE
C.T -CONDENSER TEMPERATURE
M.F.R - MASS FLOW RATE

Load-3 Graph

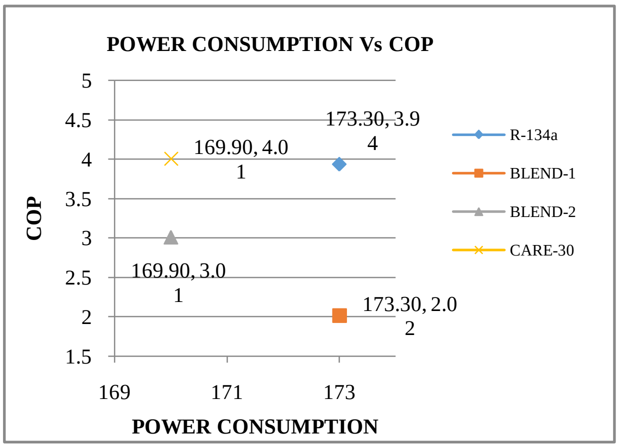


Figure 17 Variation of R.E vs. C.T

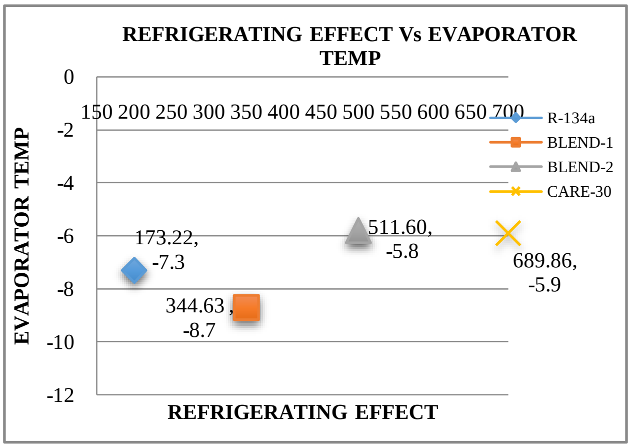


Figure 18 Variation of M.F.R vs.E.T

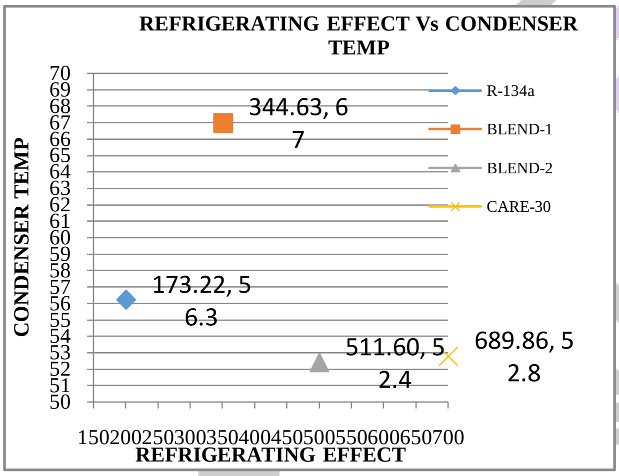


Figure 19 Variation of R.E vs. C.T

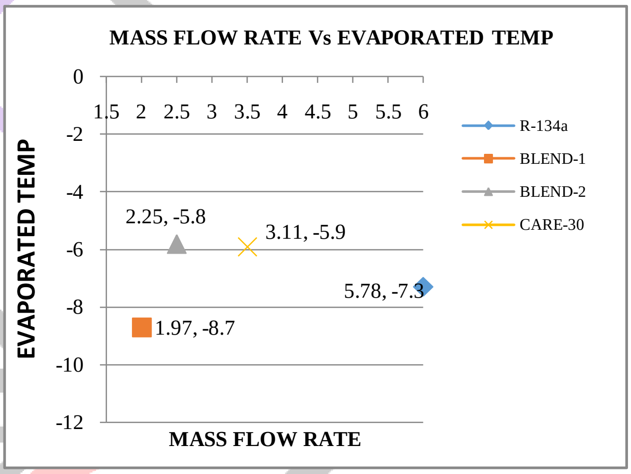


Figure 20 Variation of M.F.R vs. E.T

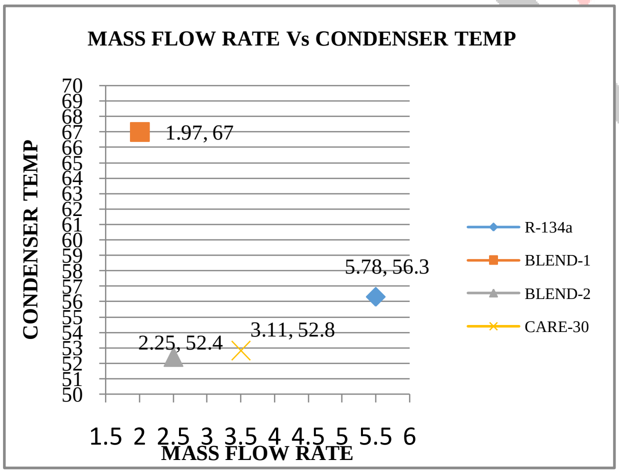


Figure 21 Variation of M.F.R vs. C.T

P.C - POWER CONSUMPTION
COP – COEFFICIENT OF PERFORMANCE
R.E - REFRIGERATING EFFECT
E.T - EVAPORATOR TEMPERATURE
C.T -CONDENSER TEMPERATURE
M.F.R - MASS FLOW RATE

V. CONCLUSION

From this Experiment, the Coefficient of Performance of the Blended Hydrocarbon CARE-30 (R290/R600a) mixtures is high when compared with the R134a refrigerant & Hydrocarbon Blend Mixture at Different Mass Ratio.And 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 CARE-30 (R290/R600) hydrocarbon than that of R134a refrigerant & Hydrocarbon Blend Mixture at Different Mass Ratio.R134a refrigerant has higher GWP. Hence permanent solution is necessary. CARE-30 (R290/R600a) with zero ODP and negligible GWP. Hence CARE-30 (R290/R600) has been be used as an alternative refrigerant.

VI. FUTURE ENHANCEMENT

- To study the effect of new efficient, minimum GWP, minimum ODP and environmental friendly refrigerants.
- Innovation of new refrigerant mixture having high COP with less environmental impact.
- To develop a mathematical model by considering multiple factors so that experimental investigation can be minimized.

REFERENCES-

[1] Mukesh K. Agrawal, Dr. Ashok G. Matani, Evaluation of Vapour Compression Refrigeration System Using Different Refrigerants-A Review, International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 4, October 2012

[2] Barathiraja.K1, Allen Jeffrey.J2, Attin kishore.R, Brito Raj.S, Ashwath Raj.A, Jayakumar.S Experimental Investigation on R 290 and R 600a In a Vapor Compression Refrigeration, International Journal of Science, Engineering and Technology Research (IJSETR) Volume 6, Issue 3, March 2017, ISSN: 2278 -7798

[3] M. Ramesh Kumar*, S. Siva Subramanian**, R. Arun Kumar*** & A. Sankara Narayana Murthy**** COMPARATIVE STUDY OF R600a AND BLENDS OF (R600a /R1270) AS DOMESTIC REFRIGERANTS, International Journal of Multidisciplinary Research and Modern Education (IJMRME) ISSN (Online): 2454 - 6119 (www.rdmodernresearch.org) Volume II, Issue I, 2016

[4] Jyoti Soni1* and R C Gupta1PERFORMANCE ANALYSIS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM WITH R404A, R407C AND R410A International Journal of Mechanical Engineering and Robotics Reserch Published Issues 2013 Volume 2, No. 1, January 2013 .

[5] Ashish Patidar 1, Amitesh Paul 2 Performance Analysis of Vapour Compression Refrigeration System Utilizing Different Refrigerant, INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY [Patidar , 3(7): July, 2014] ISSN: 2277-9655

[6] Josua P Meyer The performance refrigerants R-134a, R-290, R404A, R-407C and R-410A in air conditioners and refrigerators January2000DOI:10.1615/ICHMT.2000.TherSieProcVol2TherSieProcVol1.80

[7] Horaţiu Pop1, Gheorghe Popescu1 THERMODYNAMIC STUDY OF R290 AND R600 BLENDSUSED AS ECO-REFRIGERANTS October 2010, Vol.9, No. 10, 1395-1400

[8] Mao-Yu Wen Ching-Yen Ho ,Evaporation heat transfer and pressure drop characteristicsof R-290 (propane), R-600 (butane), and a mixtureof R-290/R-600 in the three-lines serpentine small-tube bank Applied Thermal Engineering 25 (2005) 2921–2936

[9] DR Brown N Fernandez JA Dirks ,The prospect of alternative to vapour compression technology for space cooling & food refrigeration March,2010]

[10] G. Lampugnani Embraco Europe S.r.l. Hydrocarbons as a R134A Alternative inDeveloping High Efficiency Compressors International Compressor Engineering Conference 1998]

[11] Bukola . bolaji,Thermodynamics analysis of hydrocarbon refrigerants in a subcooling refrigeration system, journal of engg. Research Vol-I june 2013]

[12] M.A. Hammad, M.A. Alsaad, The use of hydrocarbon mixtures as refrigerants in domestic refrigerators, Applied Thermal Engineering 19 (1999) 1181–1189

[13] Bansal PK, Martin A. Comparative study of vapour compression, thermoelectric and absorption refrigerators 2000; 24(2):93-107.