iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** IV **Month of publication:** April 2018

DOI: http://doi.org/10.22214/ijraset.2018.4767

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Performance Investigation of Refrigerants R290 and R134a as an Alternative to R22

R. S. Powade[1], A. A.Rane[2], A. D. Rane[3], O. S. Sutar[4], V. S. Bagade[5]
[1, 2, 3, 4]Department of Mechanical Engineering, Finolex Academy of Management and Technology-415639 Maharashtra, India
[5]Assistant Professor, Department of Mechanical Engineering, Finolex Academy of Management and Technology-415639 Maharashtra, India

Abstract: Air conditioning system works on principle of vapour compression refrigeration cycle. Efficiency of air conditioning system depends on the properties of refrigerant. But currently used refrigerants (HCFCs) such as R12, R123 has large amount of Global Warming Potential (GWP) and Ozone Depletion Potential (ODP). According to Montreal protocol and Kyoto protocol these refrigerants are promised to be banned after 2020. One of the ways to reduce GWP and ODP is the use of alternative eco-friendly refrigerant such as hydrocarbon and blend refrigerant mixture. In this study, analysis of performance of two alternative refrigerants, R290 and R134A, along with R22 are done. Experiments were perform on different refrigerant under predetermined conditions by considering various performance parameters such as refrigerant mass flow rate, cooling capacity, energy efficiency ratio, coefficient of performance, and compressor work.One ton of refrigeration (1TR) air conditioner is designed and fabricated to investigate the performance of R290 and R134a. Cooling capacity of R134a is lower in range 18%-22.5%and that of R290 is 9%-10.25% lower than R22. Energy Efficiency Ratio of R290 is 9.90% lesser than R22 and R134a is better than R22 by 7.52 %. Optimize mass quantity of R290 is 50% less than R22 and R134a is 22%lower as compared to R22 in window air conditioner.

Keywords: GWP, ODP, COP, alternative refrigerants, window air conditioner.

Nomenclature

h	enthalpy kJ/kg	S	entropy, kJ/kg K
T	temperature,°C or K	HCFCs	hydro chlorofluorocarbon
GWP	Global Warming Potential	HCs	hydrocarbons
ODP	Ozone Depletion Potential	CFCs	chlorofluorocarbons
RE	refrigerating effect, kJ/kg	HFCs	Hydro fluorocarbons
COP	coefficient of performance	Cp	entropy, kJ/kg K
W	isentropic compressor work	VCR	Vapour Compression Refrigeration
P	pressure, MPa	m_{ref}	Mass Flow rate of refrigerant

I. INTRODUCTION

As per the tendency of human beings to follow urban lifestyle, air conditioner has become daily use application from a luxurious application. Also use of air conditioning and refrigeration systems is widely increased due to its applications in industries. Major problem occurs due to refrigerants used in air conditioning system. These HCFC refrigerants have high range of global warming potential value and ozone depletion potential value and it directly affects ozone layer. Researchers made in 80's observed that CFCs and HCFCs refrigerant gases are more responsible for the ozone layer depletion. Ozone layer is a protective shield over the earth which prevents the entry of harmful ultra violet (UV) rays to earth. UV rays are hazardous for ecosystem, human life and causes environmental issues, like climate changes and rise in temperature of earth. In 1987 at the Montreal protocol it was decided to minimize the usage of CFCs and HCFCs refrigerant like R22. R22 (Chlorodifluoromethane) chlorine contain hydrocarbon has higher GWP and ODP value than other gases. In last few years R22 became a mostly used refrigerant in various Refrigeration and air conditioning appliances because of its good performance than other refrigerant.

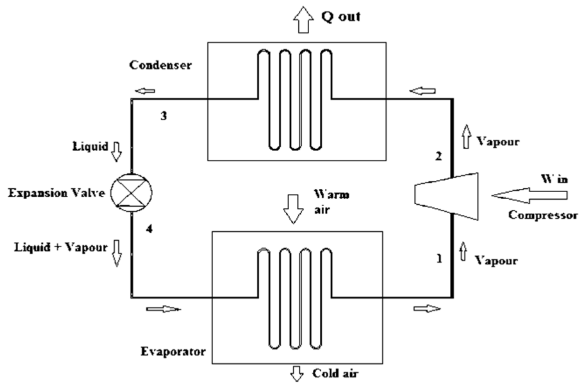


Fig.1 Simple vapour compression refrigeration cycle

Due to this reason refrigerant R22 is banned after 2020 for use in refrigeration system. In order to overcome this problem we have to use HFCs and HC blends as an alternative refrigerant to replace the R22. R134a, R290, R410A, R407c, R507 etc can be used as an alternative refrigerant for R22. The main disadvantages of R 290, R 134a, R410A, R600a and R407c have low ODP and GWP than R22.

II. LITERATURE REVIEW

J. M. Clam [1] studied the environmental impact of use of air- conditioning and refrigeration system on stratospheric ozone due to emission of HFC refrigerants and all greenhouses gases (GHGS). Thesecontribute to increase global warming. In this study he examined the trend of refrigerant losses from chiller. This study is useful for progress in reduction of emission of refrigerants and prefers alternative refrigerant for Chloroflurocarbon (CFCS).

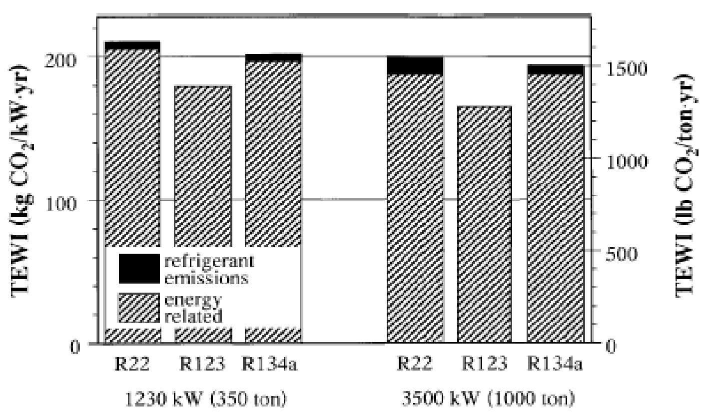


Fig.2 Greenhouse gas emissions (expressed as equivalent carbon dioxide) per unit of coding per year –TEWI-for the best available chillers in two representative capacities. [1]

From Fig.2 it is clear that direct effect of refrigerant emissions amounts to only 3-5% of the total annual total for chillers using R22 which has highest GWP among R134a and R123.These fractions drop is about 3% with R134a and 0.2% with R123 which has lower energy impact. N Austin [2] investigated the performance of VCR system with different refrigerant mixture like R152a, R32, R290, R1270, R600a and Re170 with R134a, CFC22, and CFC12. Mixture of HC290/ HC1270 (20/80) and HC290/HC600a (40/60) and Re170 were found most suitable alternative for R12, R22 and R134a.The influence of the performance parameter of refrigerant, superheating and subcooling, volumetric refrigerating capacity and COP investigated for different evaporating temperature. Results showed better performance coefficient values for the alternative refrigerant.M.M.Deshmukh and K.V.Mali [3] did theoretical parameter study on performance on VCR system with Hydrocarbon refrigerants such as R290, R600a, R1270 as well as their blend mixtures. The result shows that the alternative refrigerants investigated have a slightly lower COP as compared to R22 but much higher cooling effect. Blend mixtures shows high performance for replacement of R22.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

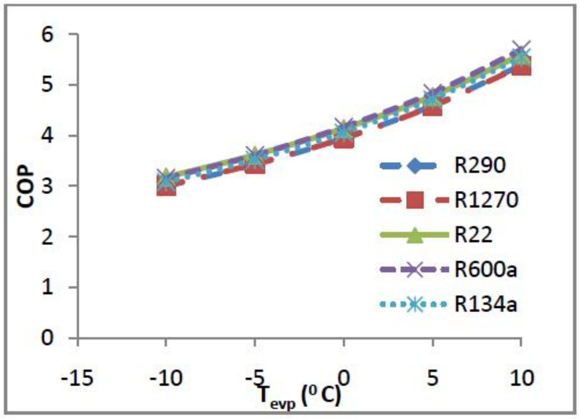


Fig.3 COP vs. Evaporation temperature [3]

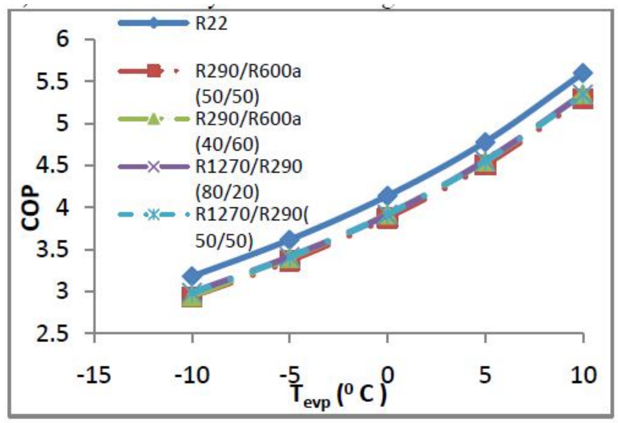


Fig.4 COP vs Evaporation temperature [3]

Fig.3 & 4shows that the pure hydrocarbon has slightly lower COP than R22 and hydrocarbon mixture also have lower COP than R22.

S. V. Shaik and T. P. ABabu[4] studied theoretical computation of performance of sustainable energy efficient R22 alternatives for residential air conditioning system. For this study R407 and four new refrigerant mixtures of alternative refrigerants R290, RE170, RE1270, R134a, R32 were used. These refrigerants have zero ODP and low GWP than R22. They concluded that performance of new refrigerant mixture NRM30 and NRM40 is better coefficient of performance, compressor discharge temperature, capacity and power consumption than R22.

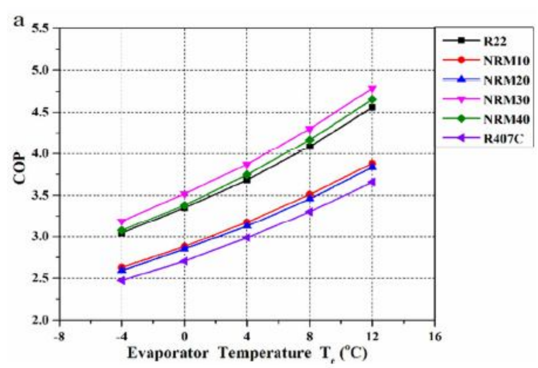


Fig.5 COP of R22 alternative[4]

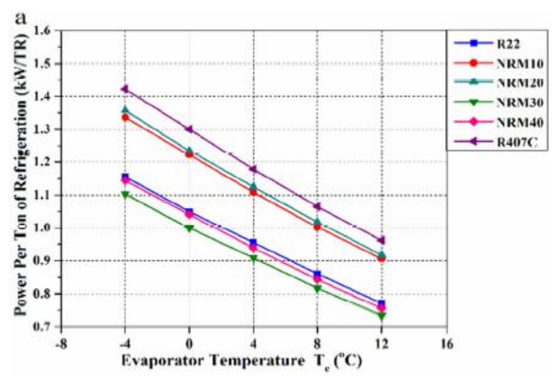


Fig.6 Power per ton of refrigeration vs. Evaporator temperature [4]

Fig.5 shows the coefficient of performance of R22 and its alternatives. It is clear that COP of all investigated refrigerants increases as the evaporator temperature increases. Due to the combined effect of refrigeration effect and compressor work on COP, COP of NRM30 and NRM40 refrigerants are higher compared to R22.Fig.6. shows all the investigated refrigerants increases with increase in evaporator temperature. It is clear that power per ton of refrigeration decreases with rise in evaporator temperature.R22 has less power per ton of refrigeration as compared to NRM10, NRM20 and R407C.

C. S. Choudhari and S. N. Sapali.[5] analysed the properties of natural refrigerant R290 in refrigeration system to check the fulfilment the objectives of Montreal protocol and Kyoto protocol. The thermodynamic performance analysis of R290 and R22 was carried out using standard vapour compression cycle with evaporating temperature range of -25^{0}C to 10^{0}C and for the condensing temperature of 45^{0}C. Refrigerant properties were obtained from REFPROP 9.0. It is observed that R290 gives lower discharge temperature which is important factor in improving life of compressor. Refrigerant mass flow rate for R290 is 50% lesser as compared to R22. The coefficient of performance with R290 closely matches with R22. Overall R290 can be better substitute to R22 in real application because of excellent environmental, thermo-physical properties and energy efficient performance.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

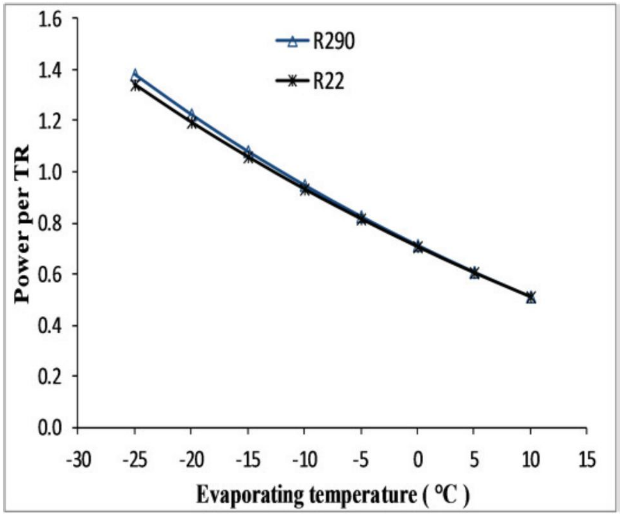


Fig.7 Variation in power per TR [5]

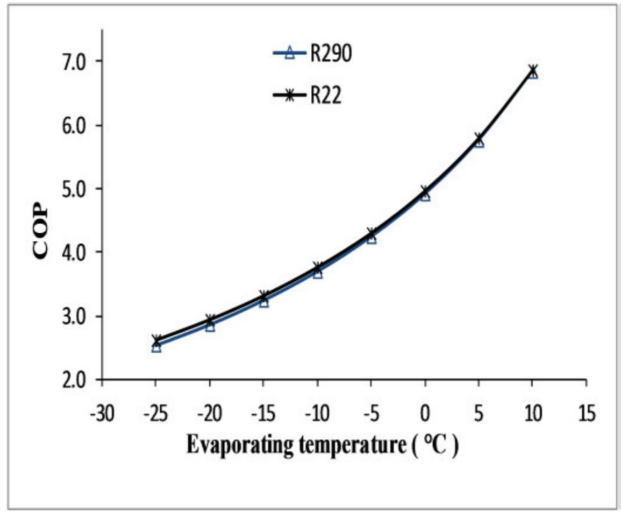


Fig.8 Variation in coefficient of performance [5]

Fig.7 shows power per TR decreases with increase in evaporator temperature.Fig.8. indicates that COP increases with increase in evaporator temperature. COP values for R290 are slightly lower compared with R22.S.Devotta *et al*.[6] worked on performance study of R290 as a substitute to R22; an experimental result shows a performance of R290 has better cooling capacity and coefficient of performance than R22. It also presents simulation of the heat exchangers of an HCFC-22. R290 had 6.6% lower cooling capacity than R22 for lower operating conditions and had 9.7% of that for higher operating conditions. Energy consumption and discharge pressure for R290 was lesser than that of R22. Pressure drop in condenser for R290 is 37-48% lesser than R22.J.Rawani et *al*. [7] compared performance of VCR system for refrigerant R134a and blend of R290 and R600a as an alternative refrigerant. COP, refrigerating effect and compressor work are the parameters considered for analysis. Mixture of R290 and R600(80/20, 70/30, 60/40 and 40/40) shows better performance in terms of compressor work, refrigerating effect, COP and volumetric cooling capacity as compared to R134a refrigerant. The mixture of R290 and R600a exhibits higher refrigerating effect as very low mass of refrigerant was required for the same capacity. Also the mixture exhibits the higher compressor work input proportion exhibits a low discharge pressure, which is more desirable in refrigeration system.

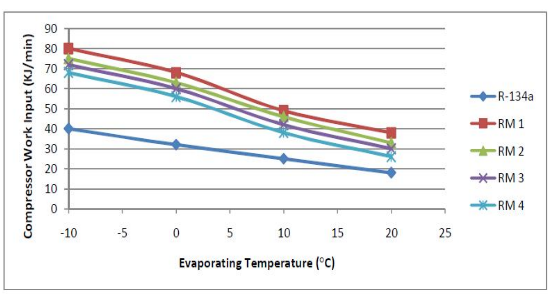


Fig.9 Compressor work input vs. evaporating temperature [7]

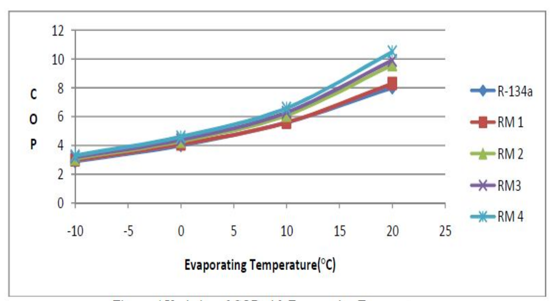


Fig.10 COP vs. evaporating temperature [7]

Fig.9 shows that compressor work decreases with increase in evaporator temperature. Compressor work using R290 and R600a are higher than R134a. The lowest compressor work is obtained using RM4.

Fig.10. shows that COP increases with increase in evaporating temperature. COP of all hydrocarbon mixtures and RM4 are higher than that of R134a.

R. K. *Gondet al* [8] did analysis of energy and exergy on a VCR system using R152, R290, R 600, R600a, R123 and R717. Performance of these refrigerants was compared with R134a.They concluded that R152, R290, R 600, R600a, R123 and R717 can be used as alternative refrigerant for R134a.They also concluded the effect of condenser temperature, evaporator temperature, coefficient of performance, exergetic efficiency and also sub cooling, superheating on the above seven refrigerant. These alternative refrigerants have good energy efficient ratio (EER) as well as good cooling effect as compared to R22. P. Kannan and A.

Manivanana [9] performed an analysis of refrigeration system using R134a, R290, R600a and various combinations of R290 and R600a. They investigation has been done for evaporator and condenser temperatures in the range of -10˚C to 40˚C. They conclude that performing the mixture ratio of R290/ R600a (70/30) is good performance in system, it most suitable alterative refrigerant for R134a and improve COP by 5.608% compared with COP of R134a. These blend refrigerant has lesser GWP and ODP as compared to other refrigerants and as per saving concern it save 6% energy consumption compared to R134a.

S. Gurav *et al.* [10] have worked on the project which is to overcome the effect of hazardous refrigerants on an environment by using alternative refrigerant R-290 and lower energy consumption by using alternative refrigerant. From research paper it is found that R290 has lowest GWP and zero ozone layer depletion and it also good performance as compared to R-22. The Compressor power required per ton to drive the system is lesser for R290 as compared to R-22. Compressor ratio, refrigerant mass flow rate required per ton is less for R290 as compared to R-22. From result COP of R290 is 1.25 times greater than COP of R-22. The cooling capacity of the system for R290 is better as compared to R22. Energy efficiency ratio for the system of R-290 is higher as compared to R-22.

III. EXPERIMENTAL INVESTIGATION

A. *Properties of Refrigerants*

Selection of a refrigerant is a critical process involving analysis of environmental, Thermo Physical and Safety property.

B. *Environmental Properties*

ODP, GWP and atmospheric life are the significant factor of refrigerant affect on environmental when released to the surrounding. ODP is an ability of refrigerant to destroy ozone molecule. GWP is an indicator of potential of refrigerant to warm the planet by action of green house gases.

R290 and R134a are non ODP and very low GWP as compared to R22. It has very less adverse effect on environmental.

Table 1 Environmental properties of refrigerants

Refrigerant	Chemical formula	Atmospheric life in year	Global Warming Potential	Ozone Depletion potential
R22	CHClF2	12	1700	0.055
R290	C3H8	0.041	20	0
R134a	$CH_2F_CF_3$	13.8	1300	0

C. *Physical and Thermo Physical property of refrigerants:*

Latent heat of evaporation of R290 and R134a are less than R22 by 80% and % respectively at a normal boiling temperature. Higher latent heat of evaporation lower is the mass of refrigerant required.

Table 2 Physical properties of refrigerants

Refrigerant	Molecular Weight(Kg/Kmol)	Normal Boiling point(˚C)	Critical Temperature (˚C)	Critical Pressure (Pa)	Latent Heat of Evaporation (KJ/Kg)
R22	86.47	-40.75	96.2	4.99	233.7
R290	44.10	-42.2	96.7	4.25	425.4
R134a	102.03	-26.1	101.1	4.06	376.8

Performance of refrigerant depends on its thermo physical properties. Density of 290 and R134a are less than R22. The lower liquid density o refrigerant required lower refrigerant mass resulting in lower friction and better heat transfer coefficients in evaporator and condenser. Refrigerant viscosity is the major source of influences condensation and boiling heat transfer coefficients. R290 and R134a have lower viscosity and higher conductivity which improve the performance of the condenser and evaporator to increase COP.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Table 3Thermo-physical properties of the refrigerants:-

Property	*R22*		*R290*		*R134a*	
	23˚C (liquid)	*59˚C(vapor)*	*25˚C(liquid)*	*55˚C(vapor)*	*11˚C(liquid)*	*50˚C(vapor)*
Pressure (MPa)	1.01600	2.4275	0.9280	1.9072	0.41461	1.3179
Density (Kg/m^3)/ volume (m^3/kg)	1194.6	0.00785	493.9	0.02288	1254.0	0.01509
Viscosity (μPa-s)	167.7	14.98	18.1	9.70	232.9	12.88
Thermal Conductivity (W/m˚C)	84.1	16.36	94.2	24.65	86.7	16.18
Specific heat (KJ/Kg˚C)	1.252	1.6075	2.708	1.478	1.377	1.246
Velocity of sound (m/s)	546	147.7	215.9	69.8	566	136.6

D. Safety Characteristics

According to ASHRAE Standard 34, refrigerant is classified as class vies refrigerant, which depend on properties like toxicity and flammability. The heat of combustion (HOC) is an indicator of how much energy, the refrigerant releases when it burns in air.
Safe use of R290 is quite possible with few precautions. Charge minimizing, seal tight system and proper ventilation are the general basis for the safer use of flammable refrigerant.

Table 4 Safety Properties of Refrigerants

Refrigerant	*LFL by mass (kg/m3)*	*LFL by volume (%)*	*Heat of Combustion (MJ/Kg)*	*Toxicity (ppm)*	*Safety class*
R22	0	0	2.2	1000	A1
R290	0.075	2.1	50.3	2500	A3
R134a	0	0	4.2	1000	A1

Data Reduction

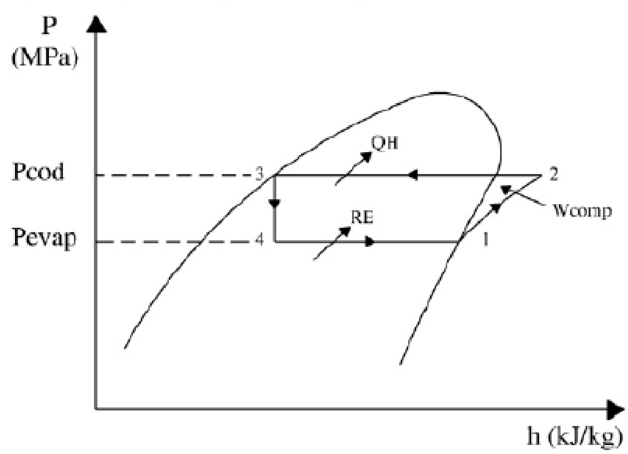


Fig.11 Pressure Enthalpy diagram

Cooling capacity, C.C. (kW) = mass flow rate of air × Enthalpy difference
Energy Efficiency Ratio EER = (C.C. / Energy Meter reading in Whr)
Coefficient of Performance COP = EER / cooling capacity
Capacity of the system = 1TR= 3.5 kW
Mass Flow rate of refrigerant, m_{ref} (kg/sec) = Capacity (kW) / (h_1-h_4)
Refrigeration Effect (RE) kW = m_{ref} ×(h_1 – h_4)

Compressor work (W) kW = $m_{ref} \times (h_2 - h_1)$

Co-efficient of Performance, (COP) = $(h_1 - h_4)/(h_2 - h_1)$

IV. RESULT AND DISCUSSION

Experiments were perform on different refrigerant under predetermined conditions by consideringvarious performance parameters such as refrigerant mass flow rate, cooling capacity, energy efficiency ratio, coefficient of performance, and compressor work.

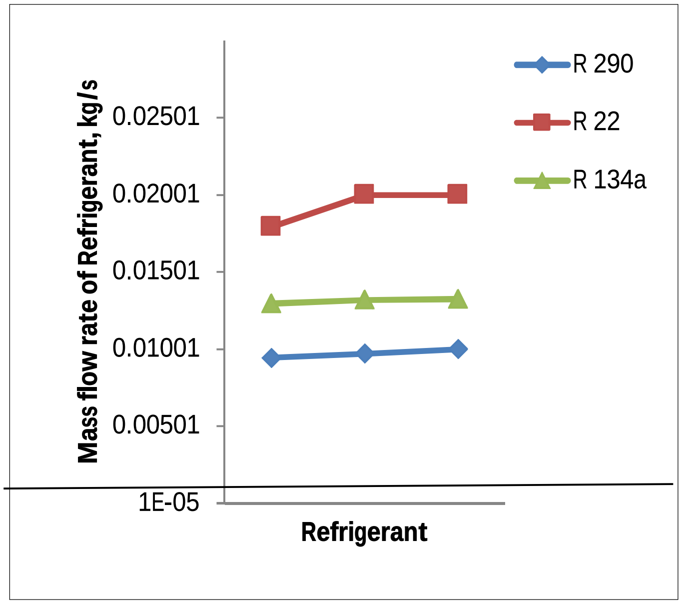


Fig.12.Refrigerant Mass flow rate of refrigerants

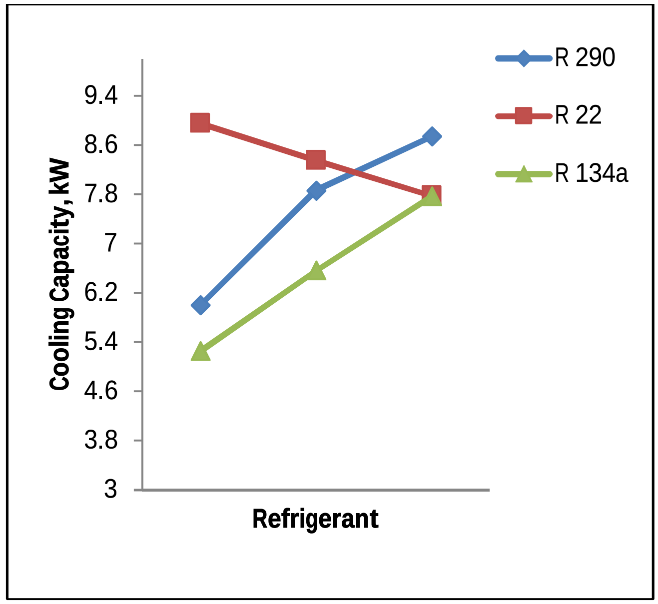


Fig.13.Cooling capacity of refrigerants

Fig.12shows mass flow rate comparison of refrigerants it is clear that mass flow rate of refrigerant for R290 is about 50.23% than that of R22 and for R134a is about 67.84% than that of R22. Fig.13. shows cooling capacity comparison of allrefrigerants and it is observed that cooling capacity of R290 is about 10.12% less than that of R22 and of R134a is about 22.01% less than R22.

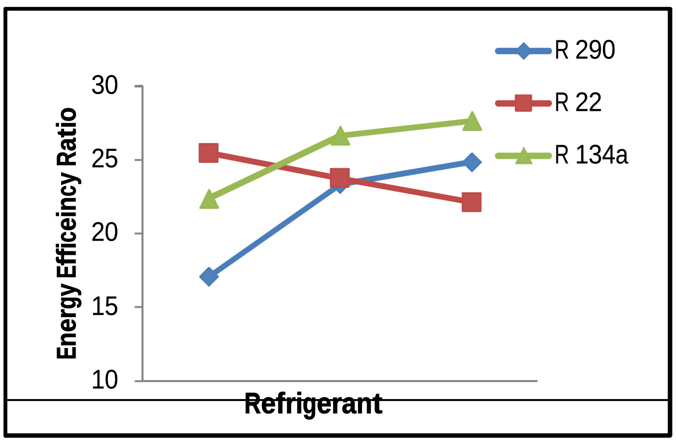


Fig.14 Energy efficiency ratio of refrigerants

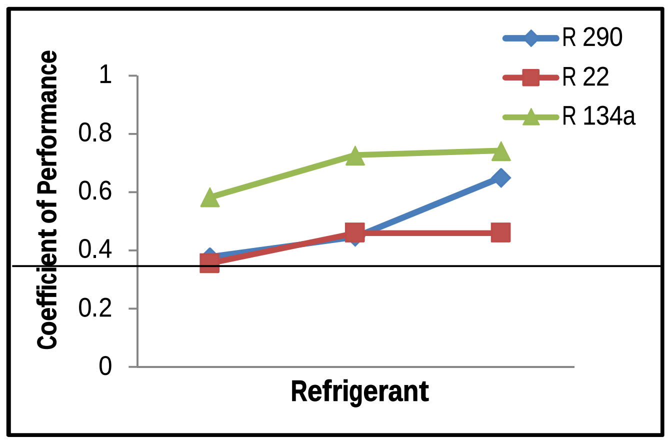


Fig.15 Coefficient of performance of refrigerants

Energy efficiency ratio comparison of all refrigerants is shown in Fig.14. It is observe that energy efficiency ratio of R290 is about 9.57% less than that of R22 and energy efficiency ratio of R134a is about 7.50% large than that of R22. Fig.15 shows the coefficient of performance comparison for refrigerants. Energy efficiency of a refrigeration system is measured by coefficient of performance(COP). COP value of R290 is 4.43% less than that of R22 and COP value of R134a is 4.08% less than that of R22. With special design of refrigeration system for R290 and R134a COP can be improved which is higher than that of R22.

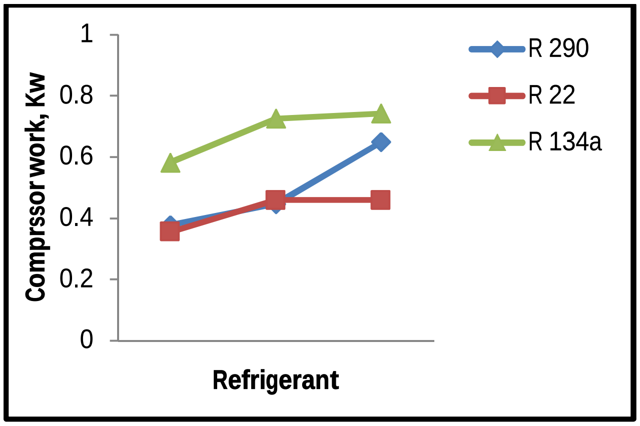


Fig.16. Compressor work of refrigerants

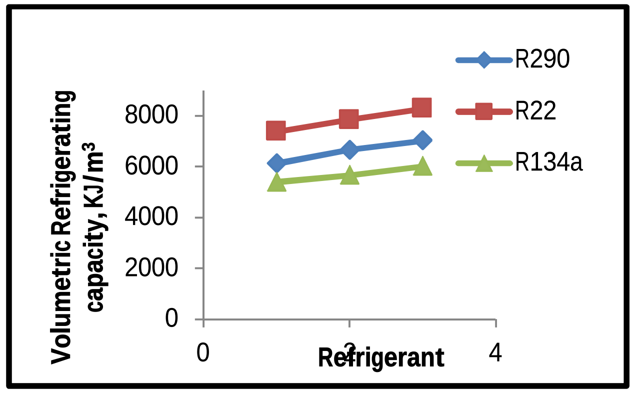


Fig.17.Volumetric refrigeration capacity of refrigerants

Fig.16 shows compressor work comparison of all three refrigerants. As mass flow rate of refrigerant increases, work of compression decreases. Compressor work forR290 is 15.63% large than R22 and for R134a is 60.82% higher than R22. Fig.17 shows the volumetric refrigeration capacity comparison for all refrigerants. The size of compressor required for particular operating conditions is determined by volumetric refrigeration capacity. Volumetric refrigeration capacity of R290 is 15.74% less than R22 and for R134a is also 27.35% less than R22.

Table 5: Parameters for refrigerants

Parameters	R134a	R290	R 22
Mass flow rate of air kg/s	1.432	1.074	0.5325
Cooling capacityKW	6.5266	7.5359	8.361
Energy efficiency ratio	25.56	21.94	23.77
COP_{actual}	7.49	6.27	6.96
Mass flow rate of refrigerant kg/s	0.0131	0.0097	0.0192
Refrigeration effectKW	3.499	3.496	3.496
Compressor Work	0.684	0.49	0.4253
Volumetric refrigeration capacity KJ/m^3	5690	6600	7833
$COP_{Theoretical}$	8	7.97	8.34

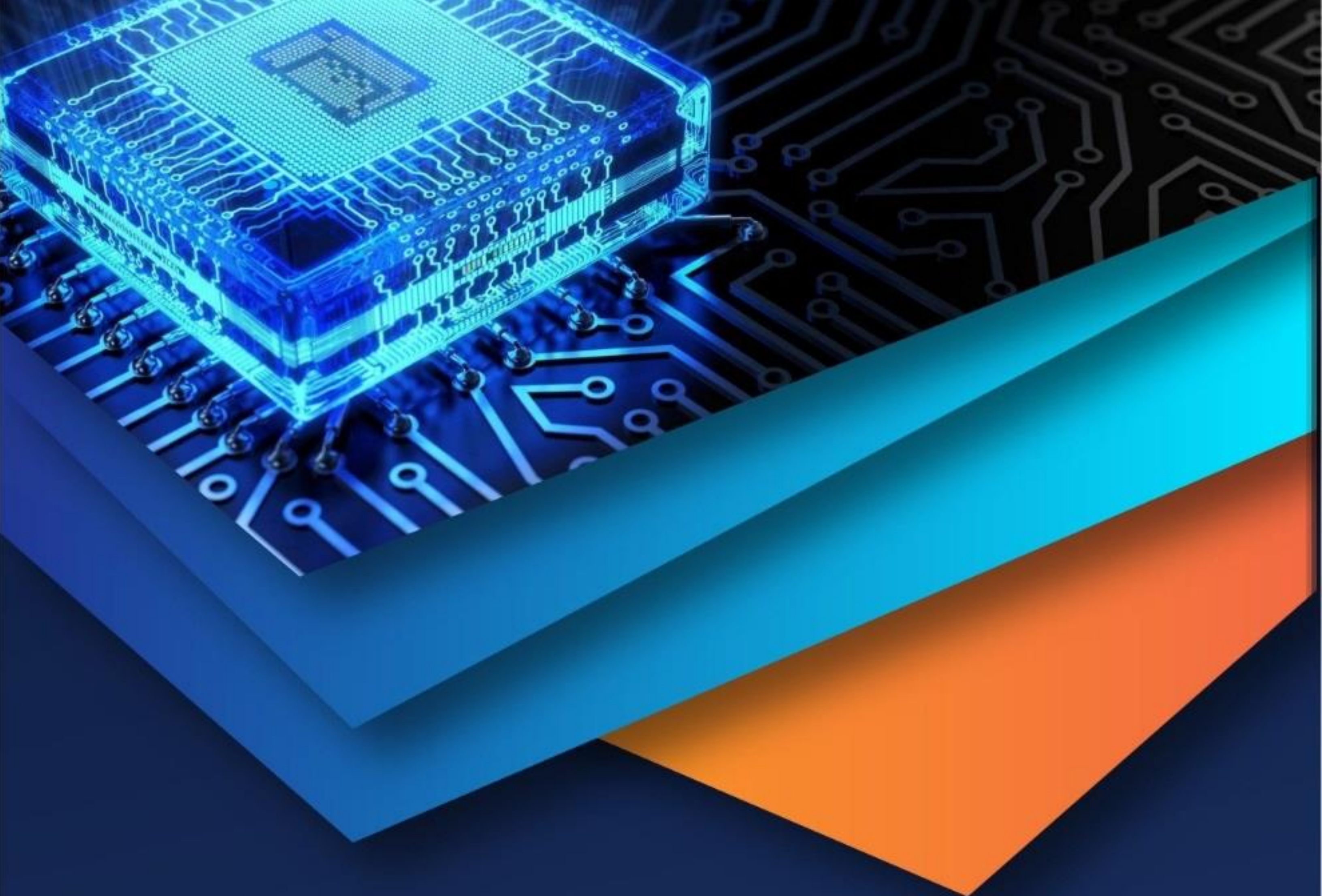
V. CONCLUSIONS

One ton of refrigeration (1 TR) air conditioner is designed and fabricated to investigate the performance of R290 and R134a. Ideal vapour compression refrigeration system is considered for performance analysis of R22 with eco-friendly refrigerants such as R290 and R134a.The parameters such as Coefficient of performance, Energy efficiency ratio, Mass flow rate, Cooling capacity, and compressor work are studied considering approximately constant evaporating temperature. Based on the experimental investigation of refrigerants R290 and R 134a as an alternative to R22following conclusion can be drawn:

A. Cooling capacity of R134a is lower in range 18%- 22.5%and that of R290 is 9%-10.25% lower than R22.
B. Energy Efficiency Ratio of R290 is 9.90% lesser than R22 and R134a is better than R22 by 7.52 %.
C. Optimize mass quantity of R290 is 50% less than R22 and R134a is 22%lower as compared to R22 in window air conditioner.
D. Compressor work for R290 is 15.63% and R134ais 6.82% larger than R22 in same capacity of refrigeration system.
E. Coefficient of performance of window air conditioner with R290 is lesser in range 8.50%- 10.40% and R134a is larger 7%-9% than R22.
F. Volumetric refrigeration capacity of R290 is 15.74% less than R22 and for R134a is also 27.35% less than R22.

REFERENCES

[1] James M. Calm "Emissions and environmental impacts from air conditioning and refrigeration systems, International Journal of Refigeration 25 (2002) 293-305.
[2] N. Austin, "Different Refrigeraants and their impact on Vapour Compression Refrigeration System". Journal of Advances in Mechanical Engineering and Sciences, Vol 2(3) 2016, pp. 29-39.
[3] MiteshM.Deshmukh, K.V.mali, "Performance Comparison of R22 refrigerant with AlternativeHydrocarbon Refrigerant",International Journal on Theoretical and Applied Research in Mechanical Engineering (IJTARME) ISSN (Print): 2319-3182, Volume -4, Issue-2, 2015
[4] Sharmas Vali Shaik, T.P.AshokBabu "Theoretical computation of performance of sustainable energy efficient R22 alternatives forresidential air conditioners", Energy Procedia 138 (2017) 710-716.
[5] C.S.Choudhari, S.N.Sapali, "Performance Investigation of Natural Refrigerant R290 as a Substitute to R22 in Refrigeration Systems"; International Conference on Recent Advancement in Air Conditioning and Refrigeration, RAAR 2016, 10-12 November 2016, Bhubaneswar, India
[6] S.Devotta,A.S.Padlkar,N.K.Sane. "Performance assessment of HC-290 as a drop-in substitute to HCFC-22 in a window airconditioner",International Journal of Refrigeration,Volume 28, Issue 4, June 2005, Pages 594-604
[7] JagnarayanRawani, Satayendra Kumar Prasad, JitendranathMahto "A project report on Performance analysis of VCRS using R134a and blend of R290 and R600a". International Journal of Innovative Research in Science, Engineering and Technology, p-ISSN: 2347-6710
[8] Raja Kumar Gond Et al, "Performance and Exergy Analysis of Vapour Compression Refrigeration System using various alternative of R134a", IRJET p-ISSN: 2395-0072
[9] P. Kannan Et al. "Theoretical analysis of vapour compression refrigeration system with R134a, R290, R600a& various ratio of R290/R600a", IJRASET-ISSN: 2321-9653.
[10] SiddharthGurav,PrajyotJadhav, SurajKamble,SwaroopMayekar, V. K. Dongare "Performance Analysis of Windo Air Conditioning Test Rig", Internationlresesrch Journal of Engineering and Technology p-ISSN: 2395-0072.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY