IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
IJARSCT
Impact Factor: 6.252
Volume 2, Issue 8, May 2022

Analysis of Effectiveness of Eco-Friendly Refrigerant Combinations in a Domestic Air Conditioner System

Mr. Aakash Mishra[1] and Dr. Shrihar Pandey[2]
Student, Department of Mechanical Engineering[1]
Associate Professor & Head, Department of Mechanical Engineering[2]
Ojaswini Institute of Management and Technology, Damoh, Madhya Pradesh, India

I. INTRODUCTION

Many published literature shows Hydroflourocarbon (HFC) and hydro carbons (HC) refrigerant mixture as the favorable replacement for HCFC22 in refrigeration and air-conditioning systems. Moreover, it was assumed that the addition of HCs(290/600) to HFC152a makes it compatible with POE oil .In this chapter the various factors that were considered to select a suitable HFC and HC mixture refrigerants with various mass proportions as drop-in substitute for HCFC22 are discussed. Since HC mixture is zeotropic in nature, the refrigerant mixture preparation and handling procedure followed for the selected mixture is also discussed.

II. REFRIGERANT MIXTURE PROPERTIES

The various properties of the refrigerants have been found from the literature that the vapor pressure, liquid density, vapor density latent heat, liquid viscosity and vapor viscosity are the significant properties to predict the alternative refrigerant and mixture properties. Thus the above mentioned properties of the refrigerant mixtures along with HCFC22 were predicted from REFPROP 7.0 Beta Version (NIST2002) software for the operating temperature ranging from 0°C to 60°C.

The proposed HFC and HC ternary mixtures with different percentage of composition to investigate for replacement of R22 are mentioned below.

- M1 -R152a-60%/R290-20%/R600-20%
- M2 - R152a-20%/R290-20%/R600-60%
- M3 - R152a-10%/R290-10%/R600-80%
- M4 - R152a-10%/R290-80%/R600-10%
- M5 - R152a-80%/R290-10%/R600-10%

Among the selected combination of refrigerant mixtures, M5 is found to be low temperature glide and M3 has low GWP (15.1), high COP and acceptable temperature glide. The Table 3.1 below presents the COP and temperature glide obtained for mixtures containing different proportions of HCFC 22 at -15oC of evaporator temperature and 30oC of condenser temperature (Khurmi 2006).

A significant amount of refrigerant mixtures that exhibit large temperature glides during the phase change. The use of such refrigerants will affect the temperature distribution in evaporator and condenser and thus impact a refrigerating system behavior. The temperature glide of refrigerant mixtures for both Te and Tc should have the acceptable limits less than 12oC at a given operating conditions. Since they are non-azeotropic (refrigerant) mixtures, exhibit a temperature variation during constant pressure phase change

GWP of blend can be calculated (from IPCC 2013),

GWP of blend (M3) = Proportion by % mass of component A x GWP of A + Proportion by % mass of component B x GWP of B + Proportion by % mass of component C x GWP of C

Where Component A = R152a, GWP of A = 124, Mass percentage = 10% Component B = R290, GWP of C = 3, Mass percentage = 10% Component C = R600, GWP of C = 3, Mass percentage = 80%

= (0.1 x 124) + (0.1 x 3) + (0.8 x 3) GWP for M3 = 15.1

Table 1: Refrigerant mixture compositions and corresponding to COP and temperature glide

Refrigerant Mixtures	R152a (%wt.)	R290 (%wt.)	R600 (%wt.)	COP	Temperature glide (°C)	
					T_{eva}	T_{cond}
M1	60	20	20	3.26	6.8	7.6
M2	20	20	60	3.33	10.8	14.2
M3	10	10	80	3.32	6.3	10.6
M4	10	80	10	3.18	5.4	4.9
M5	80	10	10	3.31	2.5	2.2

Table 2: Thermodynamic Properties of Refrigerant and Refrigerant Mixture

Refrigerant	Molecular Weight (g/mol)	Boiling Point (°C)	Freezing Point (°C)	Critical Temperature (°C)	Critical Pressure (°C)
R22	86.46	-40.81	-151.41	96.14	49.9
R152a	66.05	-24.02	-118.59	113.26	45.16
R290	44.09	-42.09	-187.67	96.67	42.47
R600	58.12	-0.055	-138.28	151.98	37.96

Figure 1 shows the variation of vapour pressure with saturation temperature. The properties are obtained from REFPROP7.0. From the graph, it could be noted that with the increase in mass percentage of HC blend, the suction pressure and discharge pressure boosts up. Among the refrigerant mixtures(M1,M2,M3,M4,M5) the vapour pressure found to be lowest for M3, which is 39.72% lower than that of R22 at 50oC.Furthermore,at 7oC evaporating temperature the pressure ratio for R22 was found to be 3.12% whereas R152a it was found to be 3.94.With the addition of HC blend to R152a the pressure ratio got reduced due to higher suction pressure of M3.As the pressure ratio reduces with the addition of HC blend in R152a,less work of compression could be expected and hence better system is possible.

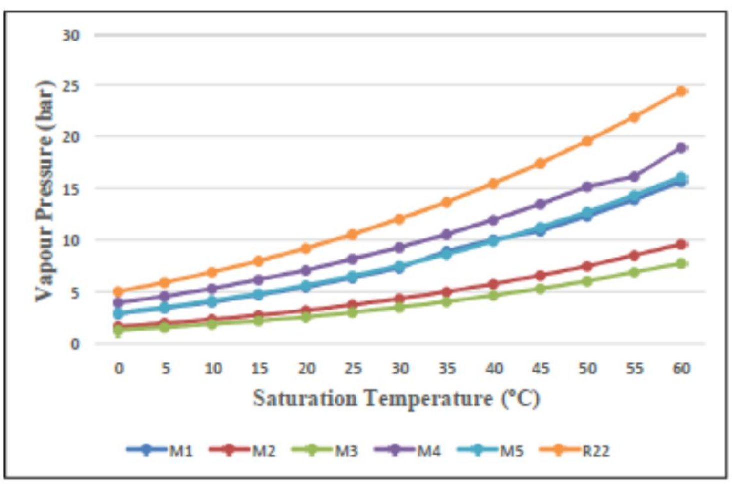

Figure 1: Variation of Vapor Pressure with Saturation Temperature

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Volume 2, Issue 8, May 2022

Impact Factor: 6.252

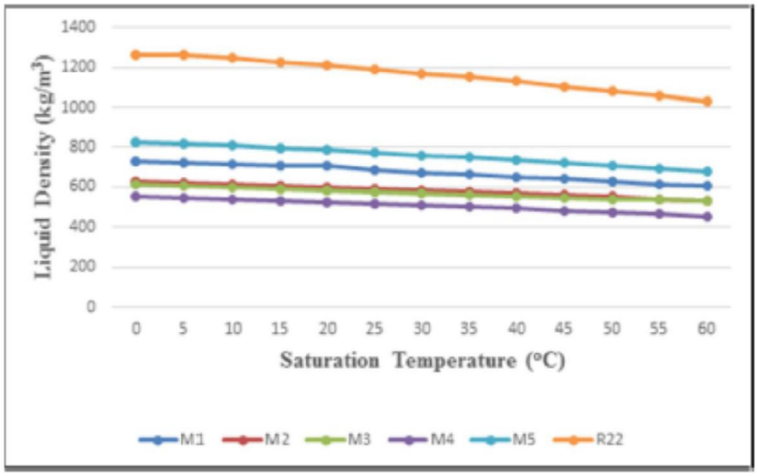

Figure 2: Variation of Liquid Density with Saturation Temperature

The charge quantity of the refrigerant is decided by liquid density property which is most significant one. The refrigerant charge used in the hermetically sealed compressor is an important parameter that affects the thermodynamic performance of the system. It has been reported that decreasing the charge quantity could reduce the cycling losses (Kuijpers *et al.* 1988). It was found that the mixtures have lesser density than R22 and with the increase in HC blend in the refrigerant mixture the density decreases.

The work of compression normally increases with the increase in the density of liquid. It is essential to study the vapour density of refrigerants used in this work since the system is vapor compression refrigeration system. Figure 3.3 represents the variation of vapour density of the refrigerants with respect to saturation temperature. It can be observed that the vapour density of the mixture 69.27% to 71.63%lower than that of conventional refrigerant R22. thermodynamic performance of the system. It has been reported that decreasing the charge quantity could reduce the cycling losses (Kuijpers *et al.* 1988). It was found that the mixtures have lesser density than R22 and with the increase in HC blend in the refrigerant mixture the density decreases.

The work of compression normally increases with the increase in the density of liquid. It is essential to study the vapour density of refrigerants used in this work since the system is vapor compression refrigeration system. Figure 3.3 represents the variation of vapour density of the refrigerants with respect to saturation temperature. It can be observed that the vapour density of the mixture 69.27% to 71.63%lower than that of conventional refrigerant R22.

III. EXPERIMENTAL SETUP

An experimental test facility has been created in order to study the performance of vapour compression refrigeration systems working with R22 and various other refrigerant mixtures. This chapter deals with the details of the experimental set up, the experimentation part, various aspects of retrofitting procedure and the data reduction procedure.

The basic arrangement of different components involved in a Vapour Compression Refrigeration (VCR) system is schematically shown in Figure 3.

The complete cycle (1-2-3-4-1) of this system involves different processes and they are given below. The Pressure-Enthalpy (P-H) chart shown in Figure 4 presents the paths taken by different processes to complete the cycle of the VCR system and the variations in pressure and enthalpy during the works done at different stages of the cycle. The cycle involves the following processes:

- **Process 1-2** Isentropic compression of refrigerant vapour in the compressor
- **Process 2-3** Constant pressure heat rejection by refrigerant in the condenser
- **Process 3-4** Isentropic Expansion of refrigerant at constant enthalpy process in the expansion device
- **Process 4-1** Constant pressure Heat addition to liquid refrigerant in evaporator

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 2, Issue 8, May 2022
Impact Factor: 6.252

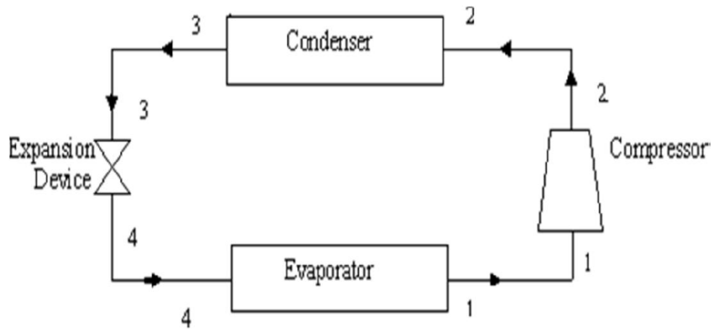

Figure 3 Schematic diagram of vapour compression system (VCRS)

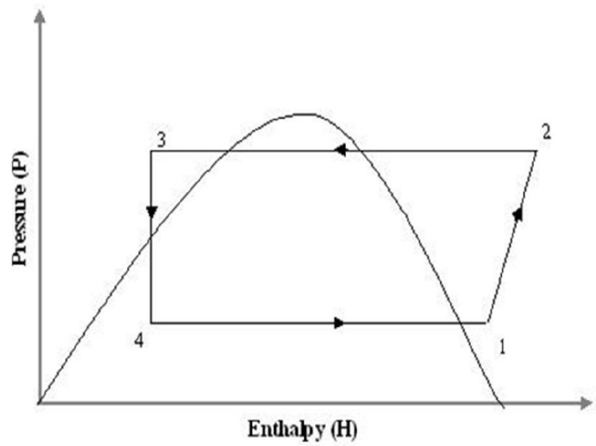

Figure 4 **Schematic diagram of vapour compression system (VCRS)**

IV. ENERGY MEASUREMENT TRIALS

Trials have been carried out on the test air conditioner with R22 and M3 refrigerants in alternate months and the energy consumption were recorded for the given operating conditions as stated in the experimental procedure.

The AC system was run with R22 refrigerant, 8 hours a day for a month and the corresponding energy consumption was recorded. The next month the same AC system was charged with M3 instead of R22 and the above procedure was carried out again. It is observed that considerable energy savings have been achieved. This procedure has been carried out for a yearlong trial. The results have been plotted as bar chart in figure 5.

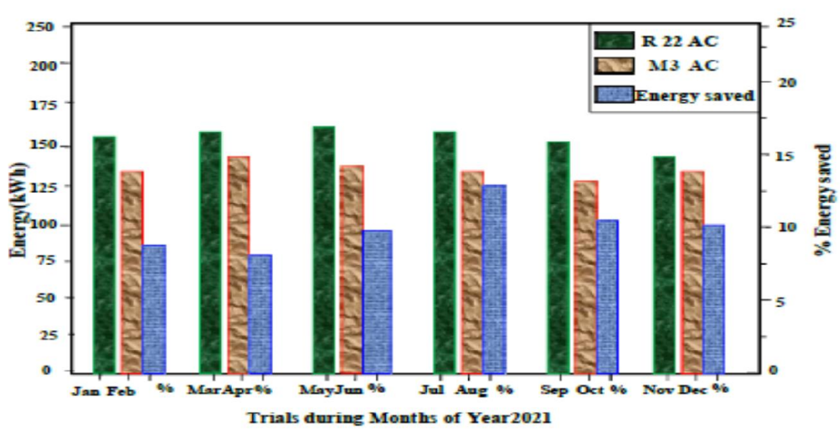

Fig 5: Energy consumption studies on R22 and M3 refrigerants AC system for the year 2021

V. CONCLUSION

The extensive experimental trials show that the proposed M3 refrigerant has distinct merits over R22 as follows:

- Better Thermo physical properties
- Lesser energy consumption
- Low global warming potential

As per the energy savings cost worked out in the section 7.5.2 the percentage savings of energy cost due to retrofitting of R22 with M3 is significantly higher to the tune of 10.3%.

In other words, due to the introduction of M3 and consequent replacement of R22 the budgetary savings for whole of India is worked out to be 24, 33, 26,160.00 (Twenty four crores thirty three lakhs twenty six thousand and one sixty) INR for 1 TR capacity indow AC used by 40% of the population.

The estimation shows that the savings for 1.5TR unit would be 29,27,20,175.00 (Twenty Nine crore twenty seven lakh twenty thousand and one hundred seventy five) INR as it is used by 50% of the population.

Similarly the savings calculated for 2TR units is 5,98,88,345.00 (Five crore Ninety eight lakh eighty eight thousand three hundred and forty five) INR as its usage is limited to 10% of the population.

These saving are significant in terms of monetary spending on Indian budget. Above all this leads to environment benefits such as lower global warming potential and eco- friendliness.

REFERENCES

[1]. Adrián Mota-Babiloni, Joaquín Navarro-Esbrí, Ángel Barragán-Cervera, Francisco Molés & Bernardo Peris 2015, 'Analysis based on EU Regulation No 517/2014 of new HFC/HFO mixtures as alternatives of high GWP refrigerants in refrigeration and HVAC

[2]. systems', International Journal of Refrigeration.

[3]. Adriano Greco, Mastrolla, R & Palombo 2003, 'R-407C as an Alternative to R-22 in Vapour Compression Plant: An Experimental Study', International Journal of Refrigeration, vol. 21, pp. 1087-1098.

[4]. Agarwal, RS & Bhatia, P 1998, 'Energy Consumption of Indian Domestic Refrigeration under Field and Laboratory Conditions A Step Towards Energy-Efficiency Standards', IIf-IIR Commissions, New Delhi, pp. 342-352.

[5]. Agarwal, RS 1998, 'Hydrocarbon Refrigerants for Domestic and Commercial Refrigeration Appliances', IIF-I1R Commissions, New Delhi, pp. 270-284.

[6]. Aprea, C & Greco, A 2020, 'Performance Evaluation of R-22 and R- 407C in a Vapour Compression Plant with Reciprocating Compressor', Applied Thermal Engineering, vol. 23, pp. 215-227.

[7]. Aprea, C, Mastrolla, R, Renno, C & Vanoli, GP 2019, 'An evaluation of R-22 Substituents Performance Regulating Continuously the Compressor Refrigeration Capacity', Applied Thermal Engineering, vol. 24, pp. 127-139.

[8]. Arcaklioglu, E 2005, 'An algorithmic approach towards finding better substitutes of Chlorofluorocarbons in terms of the second law of thermodynamics', Energy Conversion and Management, vol. 46, pp. 1595-1511.

[9]. Buero of Indian Standards (BIS) 1992, 'Room Air conditioners Specifications', Part I: Unitary Air Conditioners, IS1391, New Delhi, India.

[10]. Calm, JM & Domanski, PA 2004, 'R22 replacement status', ASHRAE J, vol. 46, no. 8, pp. 29-39.

[11]. Camporese, R, Bigolaro, G & Bobbo, S 1997, 'Experimental Evaluation of Refrigerant Mixtures as Substitutes for R-12 and R-502', International Journal of Refrigeration, vol. 20, pp. 22-31.

[12]. Chen, S., Judge, JF, Groll, EA & Radermacher, R 1994, 'Theoretical Analysis of Hydrocarbon Refrigerant Mixtures as a Replacement for R-22 for Residential Uses', International Refrigeration Conference, Indiana, pp. 225-230.

[13]. Choi, JM & Kim, YC 2002, 'The Effects of Improper Refrigerant charge on the Performance of a Heat Pump with an Electronic Expansion Valve and Capillary Tube', Energy, vol. 27, pp. 391-404.

[14]. 'Climate Change 2013: The physical science basis. Contribution of working group I to the fifth Assessment Report of the Intergovernmental panel on Climate Change (IPCC), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

[15]. Corberan, JM & Segurado, JB 2008, 'Review of standards for the use of hydrocarbons refrigerants (HCs) in air conditioners, heat pump and refrigeration equipment', International Journal of Refrigeration, vol. 3, no. 4, pp. 748-756.

[16]. Coulbourne, D & Ritter, TJ 1998, 'Hydrocarbon Refrigeration Safety: Standards and Quantitative Risk Assessments', IIF-IIR Commissions Conference, New Delhi, pp. 293-301.

[17]. David Morrison, J, Stuat Corr & Bruce E Gillbert 1997, 'Production Scale Handling of Zeotropic Blends' ASHRAE Transactions, vol. PH- 97-9-2, pp. 756-764.

[18]. Deng, J 1989, 'Introduction to Grey Theory', Journal of Grey Systems, vol. 1, no. 1, pp. 1-24.

[19]. Devotta, S, Padalkar, AS & Sane, NK 2005, 'Performance assessment of HC290 as a drop-in substitute to HCFC-22 in a window air conditioner', International Journal of Refrigeration, vol. 28, pp. 594-604.

[20]. Devotta, S, Patil, PA, Joshi, SN, Sawant, NN & Sane, NK 1998, 'Compressor Life tests with Alternatives to R-12', IIf-IIR Commissions, New Delhi, pp. 321-329.

[21]. Devotta, S, Waghjmare, AV, Sawant, NN & Domkundwar, BM 2001, 'Alternatives to R-22 for Air Conditioners', Applied Thermal Engineering, vol. 17, pp. 703-715.

[22]. Domanshki, PA 1999, 'Evaluation of Refrigerant Application'International Congress on Refrigeration', Milan, Italy.

[23]. Donald B Bivens, Charles C Allgood & Joseph J Rizzo 1994, 'R-22 Alternative for Air Conditioners and Heat Pumps', ASHRAE Transactions, pp. 562-571.

[24]. Donald B Bivens, Donna M Patron & Yokozeki, A 1997, 'Performance of R-32/R-125/R-134a Mixtures in Systems in Accumulators or Flooded Evaporators', ASHRAE Transactions, pp. 777-780.

[25]. Dongsoo Jung, Yongjae Song & Bongjin Park 2000, 'Performance of R-22 Alternatives', International Journal of Refrigeration, vol. 23, pp. 466-474.

[26]. Fatouh, M & EI Kafafy, M 2006, Assessment of propane/ commercial butane mixtures as possible alternatives to R134a in domestic refrigerators', Energy Conversion and Management, vol. 47, pp. 2644-2658.