Performance Evaluation of Propane as Substitution to Freon and Mixture of the Refrigerant in the Vapour Compression Refrigeration System

Amit Kumar Singh[1] Prof. Ravindra Mohan[2]
[1,2]IES College of Technology, Bhopal, (M.P), India

Abstract— Use of natural refrigerant R290 can play a vital role in fulfilling the objectives of the international protocols like Montreal and Kyoto. Because of environmental problems such as ozone depletion and global warming, R22 needs to be phased out on urgent basis. This paper analyzes the possibilities of R290 as a potential substitute to R22.Thermodynamic performance analysis of refrigerants R290 and R22 was carried out using standard vapour compression cycle, with evaporating temperature range of -25°C to 10°C for the condensing temperature of 45°C, based on analytical calculations. Refrigerant properties were obtained from. Performance parameters like, discharge temperature, volumetric refrigerating capacity and required mass flow of refrigerant were found to be lower with R290 when compared to R22.Coefficient of performance with R290 is slightly lower than that of with R22. However, higher COP can be expected by especially designed system pertaining to the properties of R290.Overall, R290 can be a better substitute to R22 in real applications because of its excellent environmental and thermos physical properties.

Key words: COP, Mass Flow Rate, Refrigeration Effect, Specific Work

I. Introduction

Refrigeration technology has forever played an important role in improving the human standard of living. Inventions such as the refrigerator and air-conditioner have become a necessity for comfort living. However, right from its inception, the refrigeration industry has been constantly tackling the issues of safety and environmental impact of refrigerants. Despite the constant effort from the researchers, the industry has still been a major contributor towards environmental degradation.

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A refrigerant may be a single chemical compound or a mixture (blend) of multiple compounds. Azeotropic didn't change their volumetric composition or saturation temperature when they evaporate or condense at a constant pressure these are blends of multiple components of volatilities (refrigerants) that evaporate and condense as a single substance.

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Blends- Two or more chemical compounds of mixtures of refrigerants are blends. They have multiple chemical compounds compared to a single compound is that the required properties of the blend can possibly be achieved by varying the fractional composition of the components.

II. Literature review

G. M P Yadav, P. R Prasad, G.Veeresh- Because of simplicity and low cost, capillary tubes are used as the expansion device in most small refrigeration and air conditioning systems. Another advantage is that capillary tubes allow high and low side pressures to equalize during the off-cycle, thereby reducing the starting torque required by the compressor. In this application the liquid line is usually placed in contact with the suction line, forming a counter flow heat exchanger. The liquid line is welded to the suction line in the lateral configuration. The temperature of the vapour refrigerant coming out from the evaporator is less than the temperature of the liquid coming out from the condenser. Before the expansion process, heat is transferred from the liquid line to the suction line. As a consequence this in turn reduces the refrigerant quality at the inlet of the evaporator and therefore increases the refrigerating capacity. The suction line exit temperature also increases, eliminating suction line sweating and preventing slugging of the compressor. The main objective of this project is to evaluate the performance of refrigerator with liquid line suction line heat exchanger for different lengths of heat exchanger by using R134a and R404a as refrigerants and compare with different lengths of liquid line- suction line heat exchanger.

Prof. Jignesh K. Vaghela The main aim of the research is to evaluate the different alternative refrigerants as a drop in substitute of R134a theoretically. For this purpose, thermodynamic properties of different alternative refrigerants i.e. R290, R600a, R407C, R410A, R404A, R152a and R1234yf are compared to R134a. Thermodynamic evaluation of standard rating cycle of vapour compression refrigeration system is carried out. Engineering equation solver and refprop soft wares have been used for the thermodynamic analysis purpose. From thermodynamic analysis, it is derived that R1234yf is best suitable alternative refrigerants as a drop in substitute of R134a. R1234yf has lower coefficient of performance as compared to R134a; however it is best suitable alternative refrigerants as a drop in substitute because it has very low global warming potential and can be substituted in the existing automobile air conditioning system with minimum modification.

Sharmas Vali Shaik, T. P.Ashok Babu- The present paper describes the theoretical thermodynamic performance of vapour compression refrigeration system using HFC and HC blends as an alternatives to replace the refrigerant R22. In this study thermodynamic analysis of window air conditioner with R431A, R410A, R419A, R134a, R1270, R290 and fifteen refrigerant mixtures consists of R134a,

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R1270 and R290 was carried out based on actual vapour compression cycle. All the investigated refrigerant mixtures are ozone friendly in nature and they possess GWP in the range of 0.0244 to 1.685 times the GWP of R22. Thermodynamic performance analyses of all the investigated refrigerant mixtures were evaluated at the condensing and evaporating temperatures of 54.4ºC and 7.2ºC respectively. The results show that COP for the refrigerant mixture R134a/R1270/R290 (50/5/45 by mass percentage) is 2.10% higher among the R22, R431A, R410A, R419A, R134a, R1270, R290, and fifteen studied refrigerant mixtures. The compressor discharge temperatures of all the studied refrigerants were lower than that of R22 by 4.8ºC-22.2ºC. The power consumption per ton of refrigeration for the refrigerant mixture R134a/R1270/R290 (50/5/45 by mass percentage) is 2.01% lower among R22, R431A, R410A, R419A, R134a, R1270, R290, and fifteen studied refrigerant mixtures. Overall the thermodynamic performance of refrigerant mixture R134a/R1270/R290 (50/5/45 by mass percentage) is better than that of R22 with reasonable savings in the energy and hence it is an appropriate ecologist energy efficient alternative refrigerant to substitute R22 used in air conditioning applications.

Tejaswi Saran Pilla, Pranay Kumar Goud Sunkari - Mixed refrigerant systems is reported to be thermally efficient. However, the mechanical input required by the compressor is not investigated in the literature. Hence, in the present work, two refrigerants are chosen (R-290 and R-600a) to evaluate the mechanical performance of compressor of domestic refrigerators. The refrigeration cycle consists of four major processes. The isentropic compression in the compressor, isobaric heat rejection in the condenser, isenthalpic reduction in pressure and isobaric heat addition in the evaporator. The present work aims at investigation of mechanical performance of compressor with mixed refrigerants (R-290 and R-600a). The boiling point of the each of the refrigerant is different and hence the specific volume occupied by each is different. This in turn affects the work input required. Hence, the present work is aimed at evaluating the compressor performance with mixed refrigerants. The temperature distribution during the cycle operation process is estimated. This turn enables the effective design of the compressors for domestic refrigeration systems for effective operation.

III. METHODOLOGY

Refrigerant	Chemical formula	Atmospheric life in years	Global warming potential	Ozone depletion potential
R22	$CHClF_2$	12	1700	0.055
R290	C_3H_8	0.041	20	0.000

Table 1: Environmental property of refrigerants R22 and R290

Refrigerant	Critical pressure (MPa)	Latent heat of evaporation (kJ/kg)
R22	4.99	233.7
R290	4.25	425.4

Refrigerant	Molecular weight (kg/Kmol)	Normal boiling point (°C)	Critical temperature (°C)
R22	86.47	-40.75	96.2
R290	44.10	-42.2	96.7

Table 2.Physical properties of refrigerants R22 and R290

A. *Experimental Setup*

Fig. 1: Experimental setup

B. *Experimental Procedure*

The procedure for the conduction of experiments is as follows:

- A performance test is made with the system loaded with pure R290.
- The data is treated as the basis for the comparison with the refrigerant mixtures.
- Another performance test is made with the system loaded with pure R22.
- This data is also treated as the basic for the comparison with the blended refrigerants.
- Mixture of R22 and R290 by mass in the proportion 30:70, 50:50 and 70:30 was charged in the compressor and the performance tests were conducted.
- All the tests were taken out at temperature of 35 º C.
- Half the volume of the evaporator is loaded with water throughout the experiment.
- The required data are collected and tabulated to find out COP of the system.

IV. RESULT AND DISCUSSION

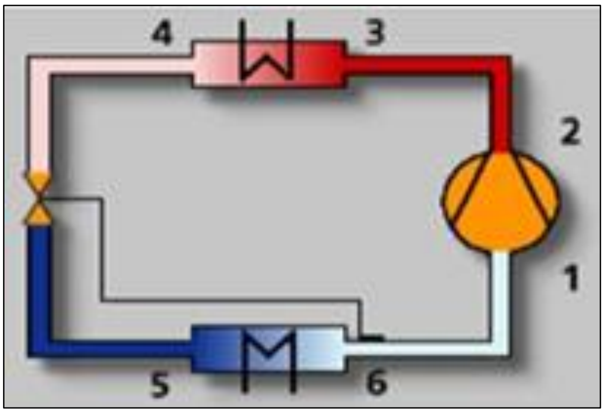

Fig. 2: Single-Stage Process

Refrigerants	Discharge Temperature (T_2 in K)	Refrigeration Effect	Specific Work
R 290	315.97	259.01	75.54
R 22	334.32	154.01	43.25

Refrigerants	COP	Mass flow rate	HP/Ton of Refrigeration
R 290	3.42	0.814	1.392
R 22	3.56	1.37	1.337

Table 3: Performance valuation of R22 and R290

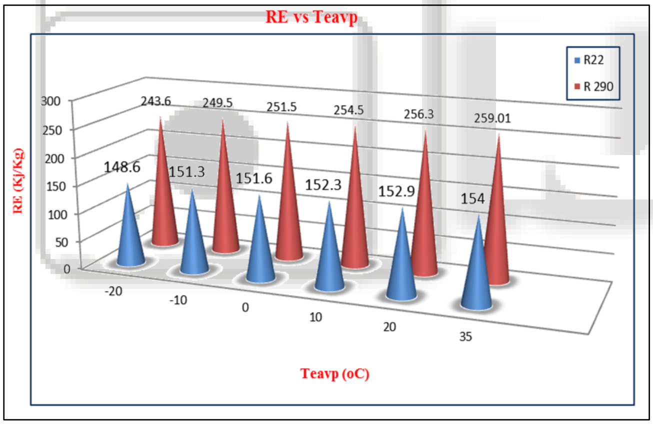

Fig. 3: Refrigeration effect Vs evaporation temp

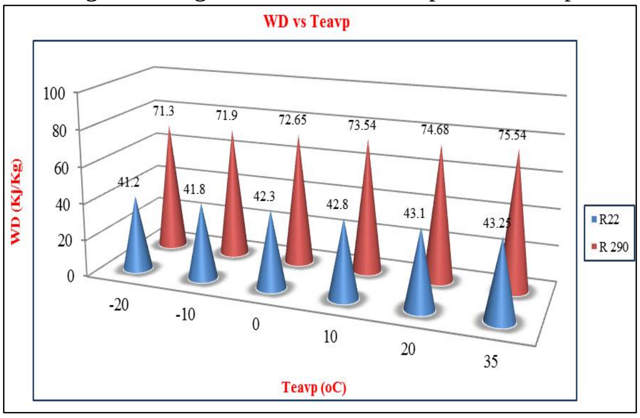

Fig. 4: Work done Vs evaporation temp

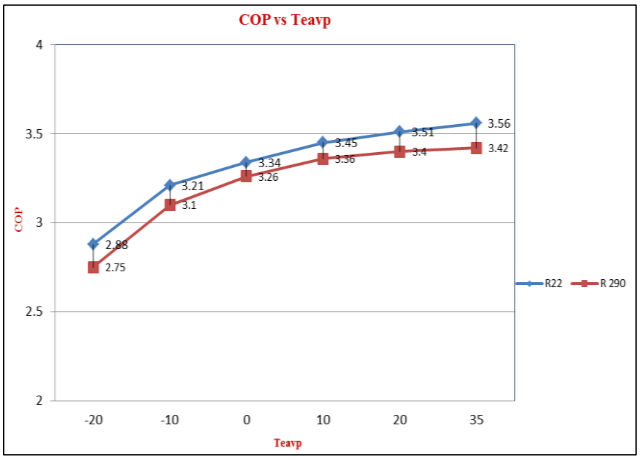

Fig. 5: COP Vs evaporation temp

R-22/ R-290	Discharge Temp (T_2 in K)	Refrigeration Effect	Specific Work
90/10	328	247.456	75.246
70/30	338	267.38	75.503
50/50	318	263.498	75.597
30/70	330	270.98	77.252
10/90	332	272.641	77.131
R-22/ R-290	**COP**	**Mass flow rate**	**HP/Ton of Refrigeration**
90/10	3.28	0.8526	1.069
70/30	3.54	0.7891	0.993
50/50	3.48	0.8007	1.008
30/70	3.51	0.7785	1.002
10/90	3.53	0.7739	0.994

Table 4: Performance valuation of Mixture of R22 and R290

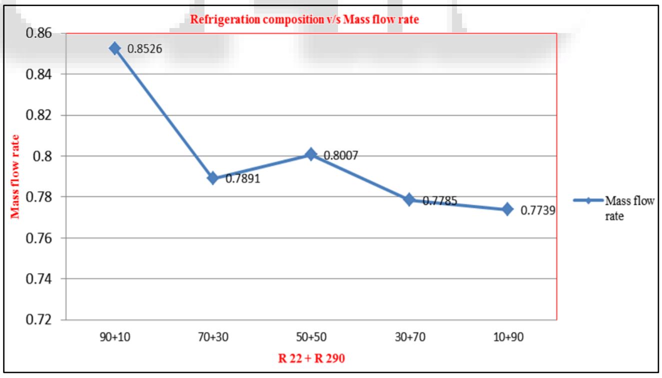

Fig-6 Mass flow rate Vs mixture of refrigerants

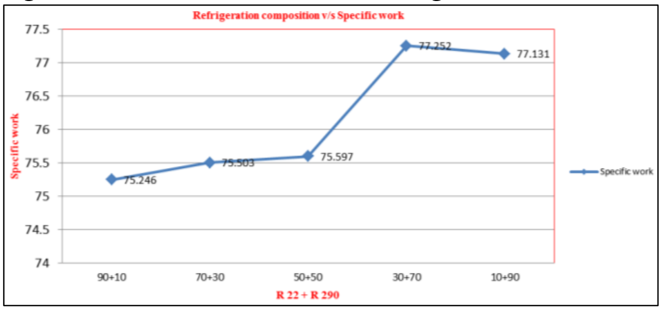

Fig. 7: Specific work Vs mixture of refrigerants

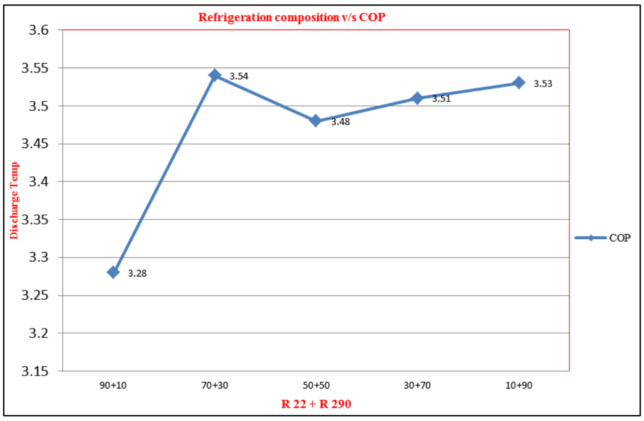

Fig. 8: COP Vs mixture of refrigerants

V. CONCLUSION

In the present study analysis of R22 and R 290 refrigerants as well as mixtures consists of Freon and propane investigated based on actual vapour compression refrigeration cycle. As the study of following conclusions are drawn.

- The COP of refrigerant mixture (3.54) showed the nearest to that of COP of R22 (3.54) among five investigated refrigerant mixtures when compared to R22 and R 290.
- Discharge temperature of compressor for all the investigated refrigerant mixtures were reduced in the range of 3.68 -22.03^{o} C when compared to reference refrigerant R22 and R 290. The lower compressor discharge temperature increases the life of motor windings. Thus R 290 is beneficial compare to others.
- The power per ton of refrigeration of R22 (1.37 kW/TR) with R 290 (1.32 kW/TR)have maximum among the five studied refrigerant mixtures .
- Overall the refrigerant mixture (R22/R290 70/30 by mass %) is an appropriate eco-friendly alternative refrigerant to replace R22 among the five investigated refrigerant mixtures from the stand point of COP, discharge temperature and power per ton of refrigeration.

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