Experimental Analysis of R-290 Refrigerant with Blending Refrigerant R-600a in Split Air-Conditioning System

Yogesh R. Dhanawade[1] Mr. S. Mitkari[2]
[1]PG Student [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]G.H.R.C.E.M.Wagholi, Pune, India

Abstract— As per the Montreal Protocol, CFCs and HCFCs are being phased out. R-22 is used in split air conditioners. This paper represents the performance study of a split air conditioner with propane (R-290) blending with R-600A as a drop-in substitute to R-134A. The use of propane (R-290) as a safe and energy efficient alternative to R-134A in a typical split air conditioner with nominal cooling capacities. The test conditions considered are as per the Indian Standards, IS 1391 (1992) Part II. The various parameters considered were based on performance with the objective to achieve maximum EER for the desired cooling capacity and better COP. As the flammability is an issue for R-290. The proper proportion of charge of the mixture taken in the spilt air conditioning system The pressure drops of R-290 and R-600a are lower as compared to R-134a.

Keywords: Split Air Conditioner, Mixture Of Propane (R290) and Isobutane (R600A), EN 378.

I. INTRODUCTION

Nowadays, the world has been experiencing global warming due to excessive emission of the gases (such as CFC, HFO, and HCFC) coming out from our domestic as well as public sector air-conditioning system. The phase-out process for the CFC and HCFC gases has been started due to the adverse effect of those refrigerants on the ozone layer and global warming. The greatest environmental effect is the destruction of the ozone layer by the chemical gases. Decrease or removal of this layer which functions as a filter against harmful ultraviolet rays can damage life on earth profoundly. After the exploration of the damage caused on the ozone layer by chlorine & fluorine-based gases, removal of this type of gases has been planned with Montreal and Kyoto Protocol. In refrigeration and air conditioning applications, HCFCs are being replaced by HFCs and natural fluids as alternative refrigerants.

At present non-ozone depleting R-600A is being considered as the major alternative refrigerants in unitary air conditioning. R-32, R-125, and R-290 are flammable. The condenser, which retains a large amount of refrigerant in the system has been optimized to reduce the refrigerant charge.

R-290 and R600a have zero ODP, approximately 3 GWP. It is a natural fluid. It has no other effect on climate, although it is considered as a volatile organic compound. It is cheap and available in plenty. R-290 and R600a is a pure hydrocarbon compound and it does not give out any toxic decomposing agents on combustion. It is compatible with the materials and lubricants used in refrigeration and air conditioning industry. Due to better miscibility with oil, the oil return to the compressor is not an issue.

II. METHODOLOGY

A. *Steps followed in the Dissertation:*

This chapter reviews the methodology followed in the dissertation. First of all, the problem is defined after surveying literature. The refrigerant is selected for the air conditioner which is suitably blending with the HFC refrigerant. Calculation of different performance parameter based on the observations was done. Optimum parameters are found by optimization. Finally, the conclusion is made regarding the results of the study.

B. *Refrigerant Selection:*

Generally, there are two types of refrigerants used for the air conditioning system. According to the ODP and GWP. The Global Warming Potential (GWP) and Ozone Depletion Potential (ODP) of R-290 is 3 and Zero, R-600A having GWP & ODP is 3 & zero.

III. EXPERIMENTAL TEST SETUP

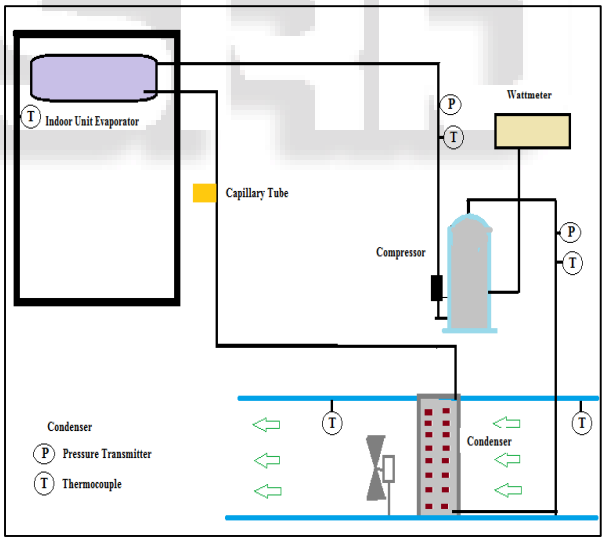


Fig. 1: Schematic diagram of the test facility

A. *Experimental Test Facility:*

As per IS 1391, the air conditioner was tested in a psychometric chamber, as shown in Fig 1. The chamber consists of two rooms of equal size, one on evaporator side and the other on condenser side. The conditioning of the air in both the rooms was done using the dehumidifiers (air conditioner), air heaters and humidifiers. In this method, measurements of dry-bulb and wet bulb temperatures of entering and leaving the air and the associated flow rates were used to calculate the cooling capacity. Nozzle type air flow rate measuring device was used to measure the volume flow

rate of air. Air temperatures were recorded with the help of precision thermometers with an accuracy of 0.1OC.

B. Safety considerations for R-290 and R-600a in a split air conditioner:

For a perfectly hermetic system, the flame cannot propagate in the interior of the system, as there will be no air inside the system. Presence of an ignition source can lead to combustion. Therefore, the following precautions were taken to ensure the safety of the air conditioner with R-290. As per EN 378, the maximum allowable charge size in a single circuit system. All standards indicate that for safe use, the charge of flammable refrigerant should be 20% of the lower flammability limit (LFL). In the case of the system is located in a closed space, safe charge of R- 290 works out to be 8 g/m3. In certain applications, this safe margin is extended up to as 25% of LFL. 1kg when the system is located below ground.

1) All tubing joints were brazed.
2) The charge of R-290 was about 500g and R-600a Even if the total R-290 leaked in the test chamber, the concentration (11.6 g/m3) would have been well below the explosive density of R-290 (43.6–175 g/m3).
3) The electrical components like a capacitor, thermostat switch, on/off switch, etc. were sealed using some means.
4) Special precautions were taken to protect the tubes from damage.
5) Every time before starting the system, the room was ventilated well.
6) Electronic HC detectors were placed in the room.

IV. EXPERIMENTAL ANALYSIS

A. Size of Condenser:

The condenser is finned tube type. The fin tubes with 7 mm OD are use with tube spacing of 21 mm in the direction of air flow. The condenser is of two equivalent parallel circuits with 12 tubes in each row. The fin spacing is 17fins/inch and a fin spacing 1.49 with thickness of the fin is 0.15 mm. The height of condenser is 19.8 inch.

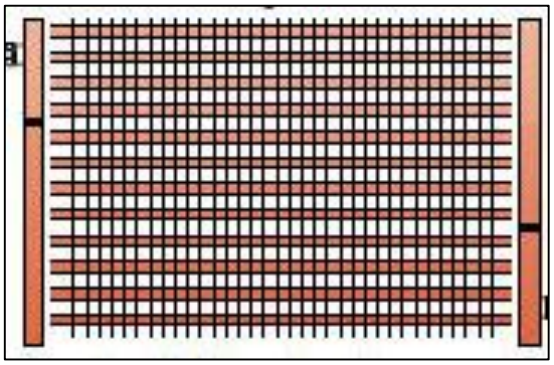


Fig. 2: Schematic of parallel flow condenser

B. Size of Evaporator:

The evaporator is a two row with four equivalent parallel circuits with 7 mm tube OD and ID 6 mm. The length of tube is 650mm. The fins are 21/inch and fin spacing is 1.20mm with thickness of 0.15mm.

Fig. 3: Evaporator

C. Capillary sizing:

The compressor inlet superheat approaches zero when capillary inner diameters lower than 1.52 mm are considered. However, due to higher flow rate of refrigerant with higher capacity compressor, larger diameter capillary is required to balance the system

D. Compressor:

The hermetically sealed rotary compressor selected because of R-290 and R600a is flammable and oil miscibility is also considered. The hydrocarbons are soluble in natural oil so special polyvinyl ester oil is used for the lubrication of compressor.

Fig. 4: Compressor.

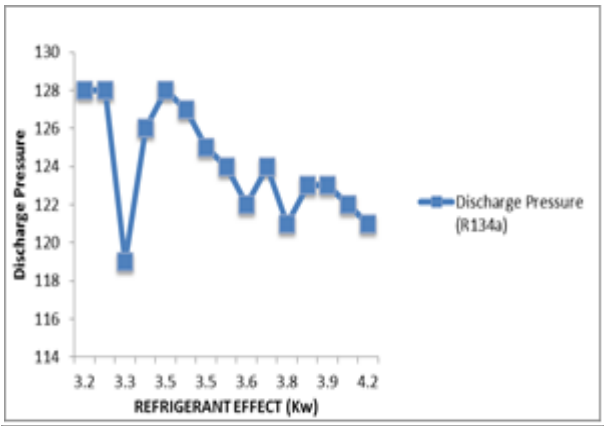
Evaporation Ranges	Refrigerants	Cooling Capacity
High Back Pressure:-15^{o}c to +15^{o}c. Low Back Pressure: -40^{o}c to -10^{o}c	R290, R134A, R600A, R404A, R452A, R449A	0.33 to 2.4 kW

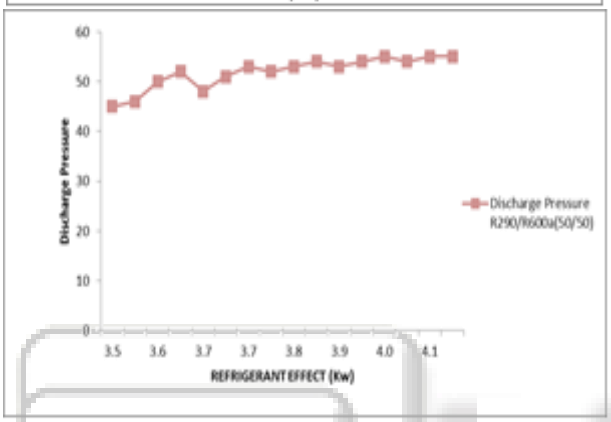
Table 1: Specification of Compressor

V. RESULT AND DISCUSSION

As per Indian Standard IS 1391 part II, 1992.The two tests carried out in the testing chamber. The outdoor room air DBT and WBT temperatures were maintained at 350C and 300C respectively, whereas the indoor air room dry bulb and wet bulb temperatures were maintained at 270C and 190C resp.

A. Refrigerating Effect Vs Discharge Pressure



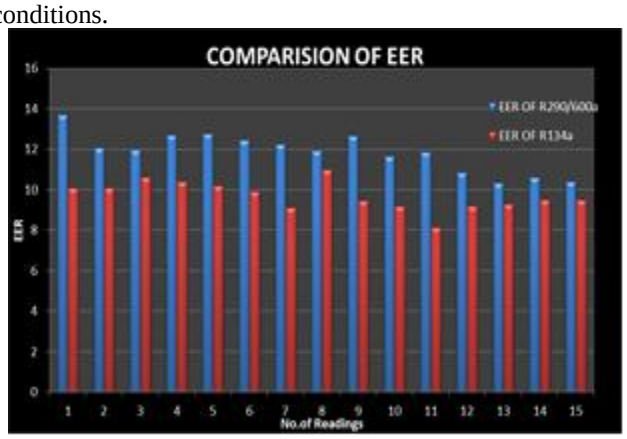


1) The first test is baseline test which is carried out with refrigerant R-134a.
2) Second test is carried out with mixture of two refrigerant i.e. R-290/R-600A with amount of 50% each.
3) A graph shows results of Refrigerating effect and discharge pressure.

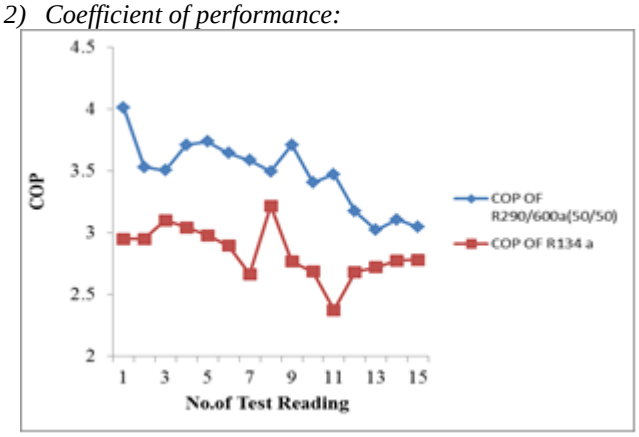
B. Experimental Results:

1) Energy Efficiency Ratio:

The test results show that EER of the mixture R-290/R-600a is as shown in graph. The average EER of the mixture is 11 and for R-134a is 10. R-134a at the same operating conditions.



2) Coefficient of performance:



As per experimental test reading the average COP of the mixture R-290/R-600a was 3.35 and the average COP of the R-134a is 2.83. The COP of mixture was higher for 50 /50 mixture.

VI. Conclusion

The performance of R290 & R600A in a split air conditioner and analyzed for different system component operating conditions. The focus of this work was to minimize R-290 charge in AC unit which will meet requirements of standards for flammability. Under drop-in conditions, the results for R290 & R600A will be showed good cooling capacity and higher EER compared to R-134A. Although the performance under drop-in is not seriously detrimental to capacity and energy efficiency, it does need the total system redesign but in small changes in design and optimization of R-290 /R 600a charge, if the unit is to work effectively and safely. The condenser with lower size tubing gave performance improvement in terms of EER and capacity. In order to minimize the charge and to achieve better cooling capacity, R-290 /R600a system requires parallel flow with fin smaller condenser and more energy efficient Compressor.

VII. Future Scope

Air conditioning manufacturer using alternative refrigerants R290 (Propane) and R32 will have marked competitive edge in India. While India is still seen to be dragging its feet over supporting global HFC phase-downs through Montreal Protocol, the use of alternative climate-friendly low GWP refrigerants are rapidly expanding in the Indian market. So, R290 with their blending mixture (R290/R600A) will be the best alternative to recently used refrigerants such as R134a. Refrigerants produced with alternative refrigerants such as R32 and R290 can be more energy efficient at high ambient temperature such as in India.

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REFERENCES

[1] Adrián Mota-Babilonia, Joaquín Navarro-Esbría, Pavel Makhnatchb, Francisco Molésa,"Refrigerant R32 as lower GWP working fluid in residential air conditioning systems in Europe and the USA", Renewable and Sustainable Energy Reviews 80 (2017) 1031-1042
[2] Atul S. Padalkar a, Kundlik V. Mali b, Sukumar Devotta,"Simulated and experimental performance of split packaged air conditioner using refrigerant HC-290 as a substitute for HCFC-22", India, Applied Thermal Engineering 62 (2014) 277e284
[3] R. Mastrulloa, A. W. Mauroa, C. Velluccia, "Refrigerant alternatives for high-speed train A/C systems: energy savings and environmental emissions evaluation under variable ambient conditions",71st Conference of the Italian Thermal Machines Engineering Association, ATI2016, 14-16, September 2016, Turin, Italy.
[4] Wang Zhang, Zhao Yang a, Jin Li, Chang-xing Ren, Dong Lv, Jie Wangb, Xin Zhang, Wei Wu, "Research on the flammability hazards of an air conditioner using refrigerant R-290", PR China, International Journal of Refrigeration 36(2013) I483-I494.
[5] J.H. Wu, L.D. Yang, J. Hou, "Experimental performance study of a small wall room air conditioner retrofitted with R290 and R1270", China, International Journal of Refrigeration 35(2012) I8603-I868.
[6] Dr. Bo Shen, Dr. Omar Abdelaziz, Dr. Som Shrestha, and Dr. Ahmed Elatar, "Model-Based Optimizations of Packaged Rooftop Air Conditioners using Low Global Warming Potential Refrigerants," Oak Ridge, International Journal of Refrigeration (2017).
[7] Atilla Gencer Devecioglu, "Seasonal performance assessment of refrigerants with low GWP as substitutes for R410 in heat pump air conditioning devices," Department of Mechanical Engineering, 21280 Diyarbakır, Turkey, Applied Thermal Engineering 125 (2017) 401–411
[8] Weier Tang, Guofeng He, "The experimental investigation of refrigerant distribution and leaking characteristics of R290 in split type household air conditioner," University of Science and Technology, Wuhan 430074, China, Applied Thermal Engineering 115 (2017) 72–80.
[9] Atilla Gencer Devecioglua, Vedat Oruça, "Characteristics of Some New Generation Refrigerants with Low GWP," University Department of Mechanical Engineering, Diyarbakir, 21280, Turkey, The 7th International Conference on Applied Energy – ICAE2015.
[10] Claudio Zilio, J. Steven Brown, Giovanni Schiochet, Alberto Cavallini, "The refrigerant R1234yf in air conditioning systems," Dept. Mechanical Engineering, Catholic University of America, Washington, DC 20064, USA, Energy 36 (2011) 6110e6120.
[11] L.Cremaschi, X Wu, A Biswas, P Deokar, "Experimental study of compressor operating characteristics and performance when using refrigerants R32, R1234yf, and two new low GWP developmental refrigerants as drop-in replacements for R410A," Oklahoma State University, School of Mechanical and Aerospace Engineering, USA.

