International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 11, November-2015

Experimental Study on Performance Parameters for Refrigerants R22, R410a and R404a at Various Air Outlet Temperatures

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***Abstract*— The motivation of this project is to investigate the performance parameters of R22, R410A and R404A refrigerants at various air outlet temperatures. The performance parameters include various thermodynamic properties like maximum discharge pressure, coefficient of performance, power consumption, heat rejection and mass flow rate. Normally for all refrigerants, thermodynamic properties decrease on achieving less temperature. As R410A is now widely used refrigerant, but on experimentation it has been observed that R404A has reached the desired temperature in short time and having highest mass flow rate when compared with R410A and R22 at four different air outlet temperatures and also there is a slight comparison observed on remaining thermodynamic properties for R410A and R404A.**

Keywords*— *Mass flow rate, Coefficient of performance, Power, Refrigerating effect, Ozone depletion potential

I. INTRODUCTION

A refrigerant is a substance or mixture, usually a fluid, used in a heat pump and refrigeration cycle. In most cycles it undergoes phase transitions from a liquid to gas and back again.

The first known instance of refrigeration was demonstrated in 1748, by William Cullen at Glasgow University. After that, in the early 19th century compression was made on the ammonia vapour into a liquid by Michael Faraday, and then followed the invention of the first refrigerator. Since the rise of climate control technologies in the 20th century the issue of environmental impact become a major concern. The main impetus was of course the ozone depleting potential of the chlorofluorocarbons (CFCs) and hydro-chlorofluorocarbons (HCFCs) commonly used in refrigeration. The HCFCs, including R-22, were scheduled for phase-out in 2010, even while bridging the development of refrigerants from early CFCs to modern hydro fluorocarbons (HFCs). The HFCs are accepted because they contain basically zero ozone depletion potential (ODP). Thus the requirement for environmentally friendly, working refrigerants necessitated the invention of refrigerant R-410A by 1991 which was introduced by Honeywell. Since then R-410A performance has been researched in various applications. Another HFC refrigerant comparable to R-410A is R-404A. Refrigerant R-404A was developed to replace CFC R-502 and HCFC R-22.

A window air conditioner is a system that cools space to a temperature lower than the surroundings. In air conditioner heat must be removed from the enclosed space and dissipated into the surroundings. However, heat tends to flow from an area of high temperature to that of a lower temperature. During the cycle, a substance called the refrigerant circulates continuously through four stages. The first stage is called Evaporation and it is here that the refrigerant cools the enclosed space by absorbing heat. Next, during the Compression stage, the pressure of the refrigerant is increased, which raises the temperature above that of the surroundings. As this hot refrigerant moves through the next stage, Condensation, the natural direction of heat flow allows the release of energy into the surrounding air. Finally, during the Expansion phase, the refrigerant temperature and pressure are lowered by adiabatic expansion process. This cold refrigerant then begins the Evaporation stage again, removing more heat from the enclosed space. A typical diagram of a window air conditioner which works according to the process explained above is shown in the figure.

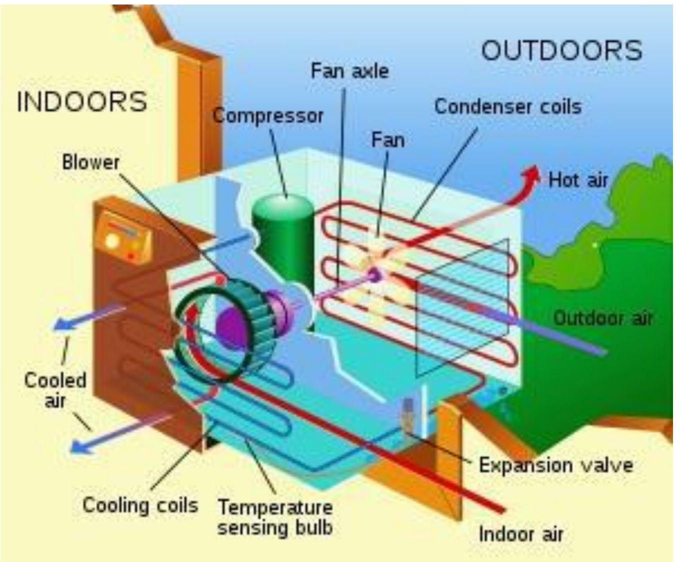

Fig 1 Typical diagram of window air conditioner

The suitability of a refrigerant for a certain application is determined by its physical, thermodynamic, chemical properties and by various practical factors. There is no one refrigerant which can be used for all types of applications. If one refrigerant has certain good advantages, it will have some disadvantages also for a particular application. Hence, a refrigerant is chosen which has greater advantages and less disadvantages.

II. LITERATURE REVIEW AND APPROACH

[1]M.Ashok Chakravarthy, M.L.S.Deva Kumar has done an Experimental Investigation of an Alternate Refrigerant for R22 in Window Air Conditioning System. A window-type air conditioning system is selected for the tests conducted with three different types of refrigerants. These air conditioning units are spread widely in their applications and are circulating R-22 as a refrigerant. In this project, two zeotrope blend refrigerants were selected in the window type air conditioner system viz., R-407C (mixture of R-32/125/134a), R-407A (mixture of R-32/125/134a) to their better thermal properties and acceptable pressure and temperature ranges and suggested R407C and R407A are nearly having same performance compare to R22.

[2]S.Venkataiah & G. Venkata Rao have done Analysis of Alternative Refrigerants to R22 for Air-Conditioning Applications at Various Evaporating Temperatures and their paper presents the simulation results of a 1.5 ton capacity room air conditioning system with some selected refrigerants that have been assessed for their suitability as alternative refrigerants to R22 for air conditioning applications and suggested no refrigerant is having better performance over R22 in all parameters.

[3]Computational analysis of the performance of ozone friendly R-22 alternative refrigerant in vapour compression air conditioning systems by Bukola Olalekan Bolaji, Zhongie Huan investigated the performances of two ozone friendly, hydro-fluorocarbon (HFC) refrigerant mixtures (R410A and R419A) theoretically using computational thermodynamic analysis and compared with the performance of baseline refrigerant (R22) in a vapour compression air-conditioning system. Performance of R410A was very close to that of R22 in all the operating conditions and performance characteristics considered. Performance of R410A is slightly better than that of R22 in terms of refrigerating effect and discharge pressure.

[4]G. Maruthi Prasad Yadav1, P. RajendraPrasad2, G.Veeresh3 has done "experimental analysis of vapour compression refrigeration system with liquid line suction line heat exchanger by using R134a and R404A "and gave a conclusion that because of simplicity and low cost, capillary tubes are used as the expansion device in most small refrigeration and air conditioning systems..

[5] A Comparison of an R22 and an R410A Air Conditioner Operating at High Ambient Temperatures by W. Vance Payne and Piotr A. Domanski took R22 and R410A split air-conditioning systems and they had tested and compared as outdoor temperature ranged from 27.8 °C (82.0 °F) to 54.4 °F (130 °F). The R410A system tests were extended to 68.3 °C (155.0 °F) ambient temperature with a customized compressor. Capacity and efficiency of both systems decreased linearly with increasing outdoor temperature, but the R410A system performance degraded more than the R22 system performance. Operation of the R410A system was stable during all tests, including those with the customized compressor extending up to the 68.3 °F (155.0 °F) outdoor temperature and resulting in a supercritical condition at the condenser inlet. No noticeable changes in noise level or operation of the system were noted.

From these studies, came to know that most of the investigations are carried by taking R22 as a baseline refrigerant and it is widely used in air conditioners, due to its high ozone depletion potential still investigations are going on for the replacement of R22. There is no refrigerant which can satisfy all the performance parameters and have to select a refrigerant depending upon the requirement. Some of the investigations are carried by replacing the components of the system or by adding some more components to the system to increase the performance.

As we already know that so many refrigerants are available in the market but particularly one refrigerant cannot satisfy all the human requirements in terms of performance parameters. So many investigations are made on the refrigerants in terms of performance parameters but maximum are concentrated on C.O.P. only, but beyond C.O.P, time taken to reach the desired temperature is also very important as so many industries and medical sectors need refrigerants which can achieve the desired temperature in very short time as more amount of heat can be liberated in that areas. This study investigates the performance parameters of the three selected refrigerants namely R22, R410A and R404A. These three are selected because recently most of the investigations on the refrigerants are made by taking the R22 as a baseline refrigerant and so many studies suggested that R410A, R404A refrigerants can replace the R22. So, in this aspect want to do a experimental study on the refrigerants to suggest the best option for a particular parameter.

III. EXPERIMENTAL SET UP

A window air conditioner of 1 ton refrigeration capacity was selected to be as a test rig. The unit is having reciprocating compressor. The condenser and evaporator coils are made up of copper with smooth inner tube surface. Both compressor and condenser fins were made of aluminum. We have to fill 850ml of refrigerant in the test rig as it is one tone refrigerating system.

Charging without the aid of any equipment requires a high level of skill and human judgment. Sometimes charging is done without the aid of any equipments, this system uses suction pressure and discharge pressure as indicative of the charge quantity. However, this needs a high level of skill and human judgment. Compressor oil also has to be changed depending upon the refrigerant selected. The window air conditioner utilizes refrigerant R-22 and mineral lubricating oil. The refrigerant may be charged in a liquid or vapour modes. This is limited by operating factors, such as the amount of refrigerant and time of charging.

Fig 2 Experimental set up of window air conditioner

IV. EXPERIMENTAL PROCEDURE

1. The taken window air conditioner is having R22 as a working refrigerant and experiment is conducted at 34^0C room temperature.
2. Keep the test rig on levelled surface. Keep the system in a closed cycle.
3. Give power supply to the system and ensure that all the Electrical connections are properly made.
4. Start the evaporator fan.
5. Start the compressor.
6. Allow the system to reach the preferred temperatures.
7. Take readings as per observation table.
8. After taking the readings switch off the air conditioner and release R22 refrigerant through delivery valve of the compressor.
9. Then run the system ideally for five to ten minutes to remove any contents of the previous refrigerant.
10. Now, change the compressor oil in the compressor which is suitable for R410A and charge the compressor through charging line connected to cylinder containing R410A refrigerant by maintaining the pressure of 9.652 to 10.342 bar at suction valve and after completing the charging perform the same procedure but make sure that the room has achieved the preferred room temperature (34^0 C).
11. Then repeat the same process for R404A refrigerant at same room temperature of 34^0C by changing the compressor oil.

V. EXPERIMENTAL RESULTS

A. *Air Outlet Temperature (^{0} C) Vs Power Consumption (kW):*

Fig 3 shows that for all refrigerants the power consumption decreases on achieving less temperatures, in that R404A is having highest power consumption than R22and R410A. R22 and R410A are having nearly equal consumption of power at starting then it varies.

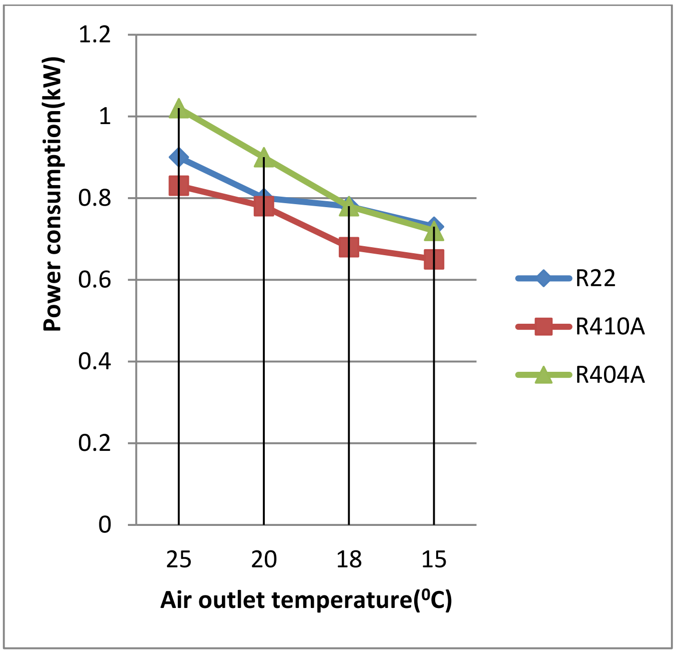

Fig 3 Air Outlet Temperature (^{0} C) Vs Power Consumption (kW)

B. *Air Outlet Temperature (^{0} C) Vs Time taken for Cooling (sec):*

Fig 4 Shows R404A has reached the desired cooling temperatures in less time compared to R22 and R410A. R22 and R410A are taking more time to reach the desired temperature.

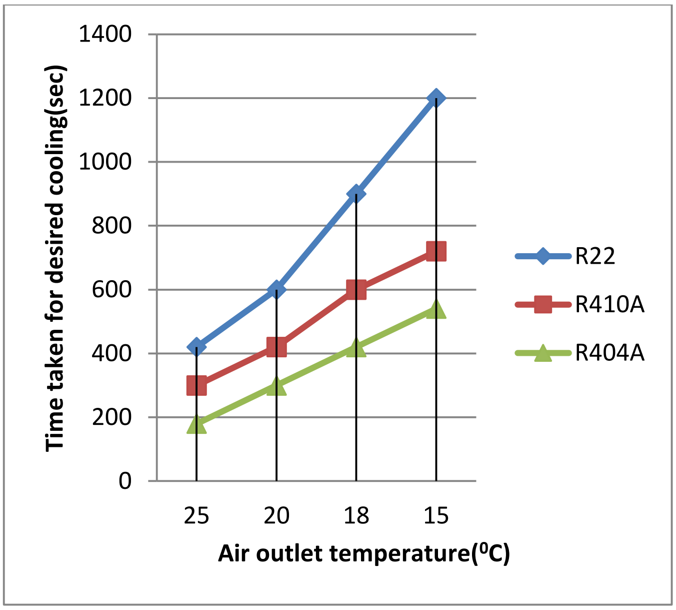

Fig 4 Air Outlet Temperature (^{0} C) Vs Time taken for Cooling (sec)

C. Air Outlet Temperature (^{0}C) Vs Mass flow rate (kg/sec):

Fig 5 shows there is a slight decrease in the mass flow rate for all refrigerants on achieving less temperature. R404A has highest mass flow rate while R410A has lowest mass flow rate.

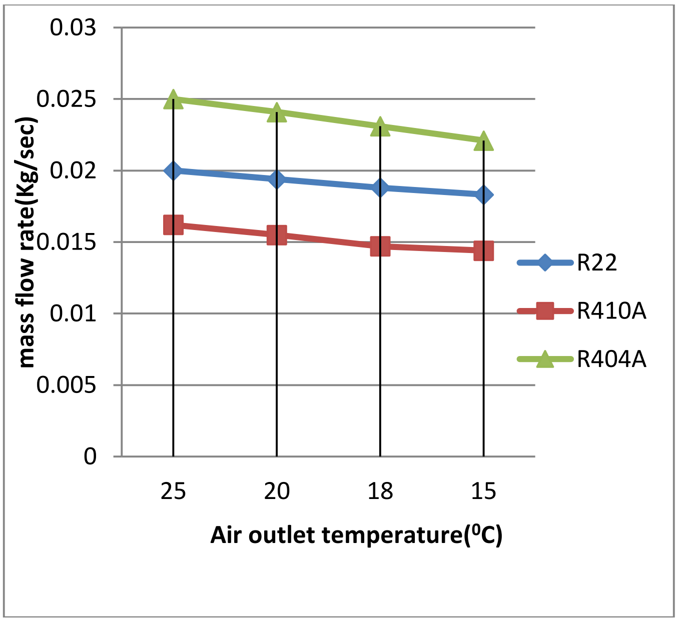

Fig5 Air Outlet Temperature (^{0}C) Vs Mass flow rate (kg/sec)

D. Air Outlet Temperature (^{0} C) Vs C.O.P.:

Fig 6 Shows C.O.P also decreases on achieving less temperatures .R410A has more C.O.P and R404A has less C.O.P value and there is not much variation of C.O.P. for refrigerants R22 and R410A.

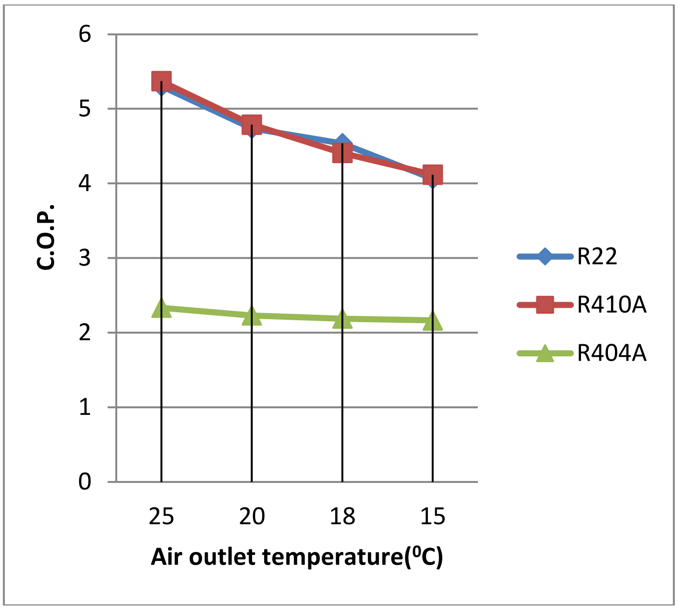

Fig 6 Air Outlet Temperature (^{0} C) Vs C.O.P.

E. Air Outlet Temperature (^{0} C) Vs Refrigerating effect (kJ/kg):

Fig 7 Shows Refrigerating effect is increasing on achieving less temperatures and it is highest for R410A and lowest for R404A.

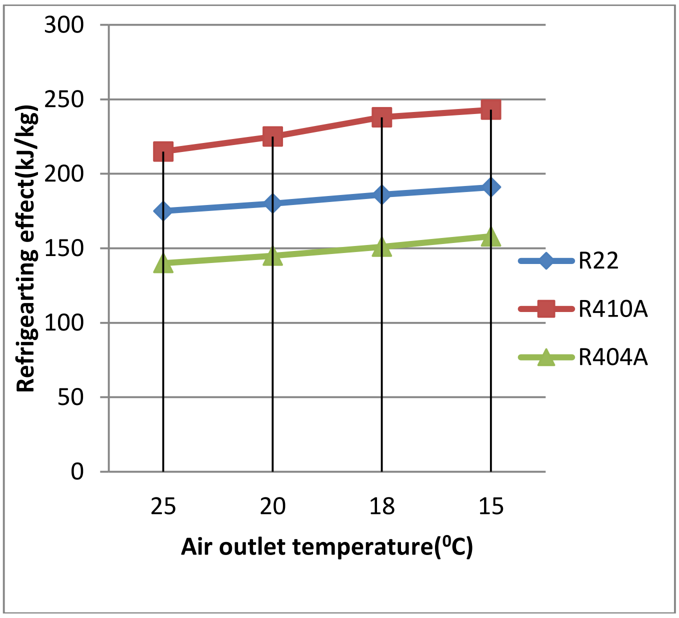

Fig 7 Air Outlet Temperature (^{0} C) Vs Refrigerating effect (kJ/kg)

F. Air Outlet Temperature (^{0}C) Vs Heat rejected in the Condenser (kJ/kg):

Fig 8 Shows Heat rejection rate in the condenser also increases on reaching less temperatures and it is highest for R410A and lowest for R404A.

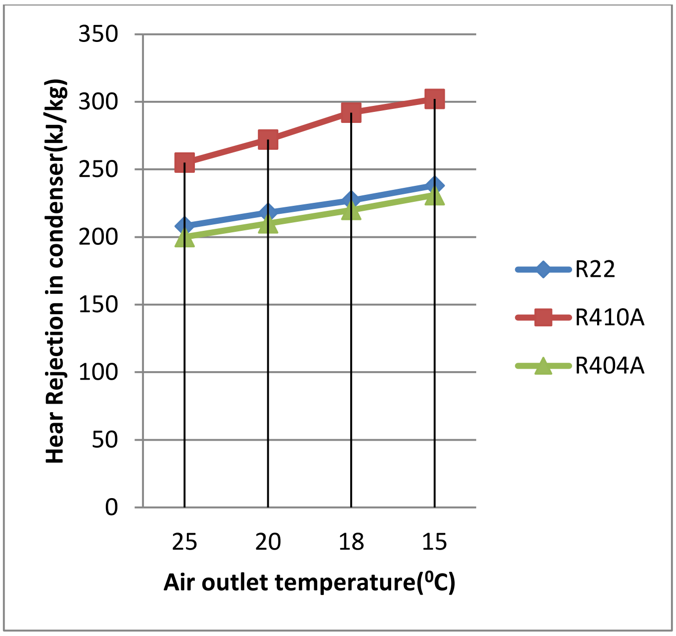

Fig 8 Air Outlet Temperature (^{0}C) Vs Heat rejected in the Condenser (kJ/kg)

G. Air Outlet Temperature (^{0}C) Vs Discharge pressure(bar):

Fig 9 shows that the discharge pressure at compressor value decreases on achieving less temperature. R22 is having high pressure values and R410A is lower.

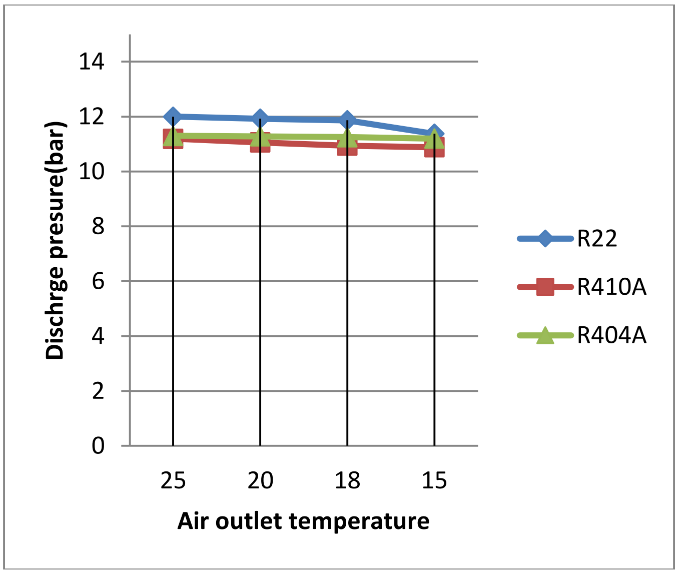

Fig 9 Air Outlet Temperature (^{0}C) Vs Discharge pressure (bar)

Depending upon the requirements the refrigerant can be chosen for various purposes i.e.

1. For high pressure ratios R22 refrigerant is preferable.
2. For achieving desired cooling effect in very less time, R404A is preferable.
3. For achieving high mass flow rate, R404A is Preferable.
4. For high heat rejection rates, R410A is preferable.
5. Best C. O. P.Can be achieved by using both R22 and R410A.
6. For optimizing power consumption R410A can be used
7. For best refrigerating effect, R410A is best option.

VI. CONCLUSION AND FUTURE SCOPE

This study was mainly concentrated on performance parameters of three different refrigerants and identified that, depends up on the requirement we have to choose the refrigerant but there is no refrigerant which is best in all parameters. This study also suggests that for achieving desired temperature in very short time R404A is preferable as it is a very important aspect for so many industrial and medical sectors. For domestic purpose R410A is preferable as it is nearly having same parameters as R22.

In future, so many refrigerant mixtures are planned to be launch in the market. So, by taking this study as a base we can perform study on selecting some more refrigerants, so that we can find a refrigerant which can give best performance in all parameters

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