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Performance Assessment of HFC Group Refrigerants in Window Air Conditioning System

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Abstract: This paper discusses the different operating conditions of three refrigerants i.e. R22, R410A and R32. For analysis 1 Ton of window air conditioner has been chosen. Basically the operating cycle is a simple vapour compression refrigeration cycle with hermitically sealed compressor. The HFC groups of refrigerants do not have any Ozone Depletion Potential and refrigerants like R32 has the advantage of lower Global Warming Potential (GWP:675) with compare to R22 (GWP:1700) and R410A(GWP:2100) refrigerants. As per the indication of Montreal and Kyoto protocol, the world community has decided to phase down the HCFC group refrigerants. The refrigeration and air conditioning industry required to evaluate new alternative refrigerants to HCFC-22 also known as R22. The performance parameters like, pressure ratio, condensing temperature, discharge temperature of the compressor, power consumption and COP of the system were analyzed and compared.

Keywords: ODP, GWP, Ton of Refrigeration (TR), COP, Discharge Temperature, Pressure Ratio

1. Introduction

The science and practice of creating a controlled climate in indoor space is called air conditioning. The refrigeration cycle can also be applied for air conditioning system, now days there are various methods of cooling systems are available, but vapour compression refrigeration system is better and efficient method for air conditioning purpose. Vapour compression refrigeration cycles have two advantages [1-3]. First, a large amount of thermal energy is required to change a liquid to a vapor, and therefore a lot of heat can be removed from the air-conditioned space. Second, the isothermal nature of the vaporization allows extraction of heat without raising the temperature of the working fluid to the temperature of whatever is being cooled [4-5].

2. Literature Review

To search for (HCFCs group) alternative to refrigerant 22, a comprehensive literature study has been carried out for various alternate refrigerants which are being used with vapour compression refrigeration system. James M.Clam [6] in this research article the author stated the important of the next stage environmental safe refrigerants as per the Montreal and Kyoto protocol agreements. The author conclude that there no ideal refrigerant which suitable for all the applications

Cavallini A, [2] conducted experiments by using ozone friendly refrigerants and compared the performance characteristics in a vapour compression refrigeration system by four different refrigerants like, 125, R134a, R143a and R152a in his investigation the R152a coefficient of performance is good with compare to the other three refrigerants and also r152a has zero ODP and very low global warming potential.The world community has been searching for alternative refrigerants, the major compressor manufacturer's plans to convert 50% in R410A and 50% in R32 by 2015, for commercial sectors for Room Air-Conditioning 85% in R410 and 15% Indonesia plans to prohibit HCFC import 2013 and HCFC production in 2015 [7-13]. Also decided to use R32 instead of R410A.Kuwait are interested in R32 and requested a contact with Daikin. Kuwait is doing a joint evaluation for R32 performance under high ambient temperature condition with Daikin as the representative of Middle East countries. In many of the research papers deal with performance comparison for different parameters as the R22 phase down from the existing air conditioning system [14-16]

3. Experimental Methodology

A window air conditioner is basically an enclosed assembly designed to be a compact unit primarily for mounting in a window, through the wall. The test unit under investigation is placed in the opening according to the specifications such that the heat rejection section is in the outdoor room and the heat absorption section is in the indoor room for a cooling test. The test unit will be powered in either the indoor and outdoor test room. Both test rooms are separately enclosed in another insulated room called controlled air space.

The basic components in a window air conditioner are as follows:

1. Compressor, 2. Condenser, 3. Evaporator and 4. Expansion valve

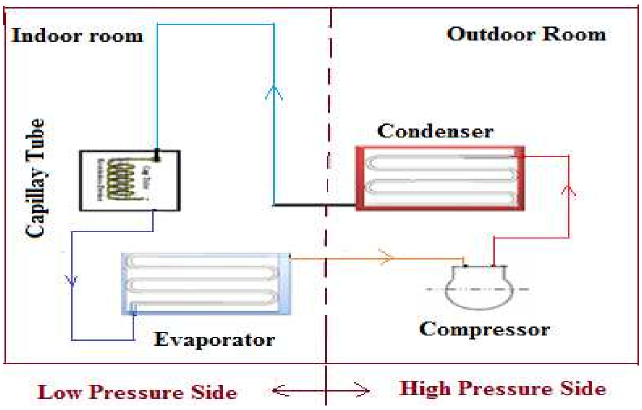

Figure 1. *System Design considerations.*

Figure 1 shows, the importance of proper system design when hermetic compressors are used on appliances, Compressors cannot over emphasized, because the motor and compressor assembly in the hermetic compressor necessitate holding mechanical, electrical and thermodynamic variables within the limits specified for safe and trouble free operations.

The P-h diagram (Moeller diagram) for refrigeration cycle which is shown in figure 2 with four basic processes are frequently used in the analysis of Vapour Compression Refrigeration cycle, process 1to 2 is Compression, process 2 to 3 heat rejection in the Condenser, process 3 to 4 Expansion (Throttling) and process 4 to 1 is Evaporation i.e. heat absorbed in the evaporator. The performance characteristics are can be computed for Compressor work (Wc), Refrigeration Effect (Q_E) and Coefficient of Performance (COP). COP = (h_1-h_4 / h_2-h_1)

Where,

h_1 and h2 are Enthalpies of Refrigerant at the inlet and outlet of compressor (kJ/kg).

h_3= h_4 are Enthalpies of Refrigerant at the inlet and outlet of expansion valve (kJ/kg).

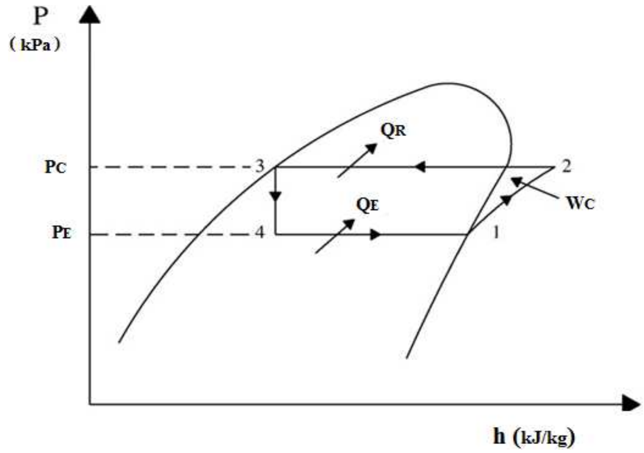

Figure 2. *P-h Diagram for refrigeration cycle.*

Figure 3. *Compressor with thermocouples.*

Figure 3, shows the measurement of temperature by attaching the thermocouple at various positions like Compressor shell (Top, Middle and Bottom locations) the selection of compressor for particular application is depends on the operating pressure and temperatures. The different types of hermitically sealed compressors are (RN, RR and RK are Rotary Compressors) and (AW–Reciprocating compressors). The temperature of the of locations in refrigeration system has been measured using with high precision RTD's and also the flow of refrigerant measured using mass flow meter device (Micro-Motion). Following will cover the key measurement required and the sensors we would typically use to acquire those measurements:

1. Temperature, 2.Pressure, 3.Power and 4.Flow

Table 1. *Standard instrument details used for calibration of temperature.*

Nomenclature	Make & odel	SI.No.	Uncertainaty	Traceable to
RTD sensor	PT-100	TIC/RTD/2	±0.25˚C	STQC

Table 2. *Standard instrument details used for calibration pressure.*

Nomenclature	Make&model	SI.No.	Uncertainaty	Traceable to
Pressure Controller With sensor	Ajay sensor 289 series	ASP 781/5	±0.018 bar	Nagman/Cert.No.2007-08/CFC/19100

Table 1&2 shows the standard instruments with their specification, which were used for measurements and error for measurement uncertainty is ± 0.13% at 95 confidence level.

Resistive Temperature Detector (RTD); Thermocouple (T-type or J-Type

4. Results and Discussions

The following conclusion has been drawn, after the comparason of both simulated and experimental results. With compare to other two refrigerants R32 refrigerants performance characteristics were found to be better.

Table 3. *Pressure Ratio.*

Refrigerant	Suction pressure				
	SET 1	**SET 2**	**SET 3**	**SET 4**	**SET 5**
R22	620.2	619.9	619.9	619.9	620
R410A	988.2	988.2	988.4	988.3	988.4
R32	1016	1016.1	1015.8	1015.5	1015.7
Refrigerant	Discharge Pressure				
R22	2147	2148	2145	2146	2146
R410A	3385	3386	3387	3386	3386
R32	3385	3386	3387	3386	3386

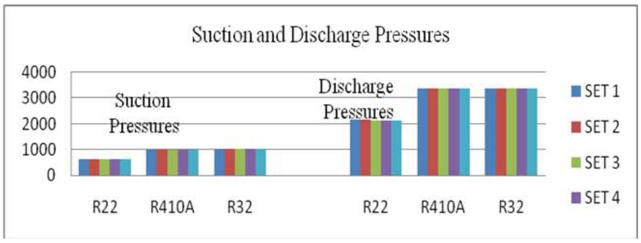

Figure 4. *Compressor with thermocouples.*

Figure 4 shows the experimental suction and discharge pressures at evaporator temperature of 7.2˚C and condenser temperature of 54.5˚C, the results obtained with respect to the pressure, from the plot for both the cases i.e suction and discharge pressure are as follows for R22 suction and discharge pressures 619.9 kPa and 2145 kPa. R410A suction and discharge pressures for 410A 988.4and 3387 kPa and for R32 the suction and discharge pressures are 1015.8 kPa and 3387 kPa, it is observed that; for all the cases the R32 attains higher suction and discharge pressures.

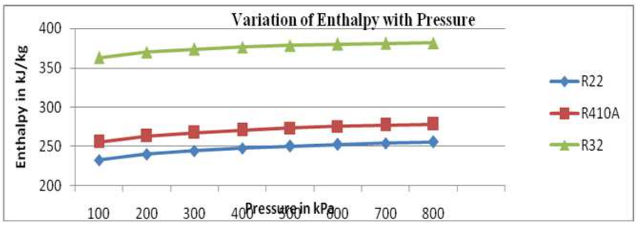

Figure 5. *Variation of enthalpy with Pressure。*

Figure 5 show the variation of enthalpy, with pressure the enthalpy is very high for the R32vand very low for R22 refrigerants. The thermodynamic concept involves vapour pressure and latent heat which is called enthalpy of evaporation.It is the indication of specific internal energy and specific flow work. It is observed from the figure that for the operating pressure of 800 kPa the enthalpy for R32 is 382 kJ/kg for R410A 280kj/kg and for R22 is 255 kJ/kg.With compare to R22 and R410A the R32 enthalpy is 33% and 27% more, this may be a advantage to R32 refrigerant.

Table 4. *Discharge Temperature for different set values.*

Refrigerants	**SET 1**	**SET 2**	**SET 3**	**SET 4**	**SET 5**
R22	89.8	89.7	89.5	89.7	89.5
R410A	89	89	89.2	89.2	89.2
R32	112	111.9	112	112.1	112.1

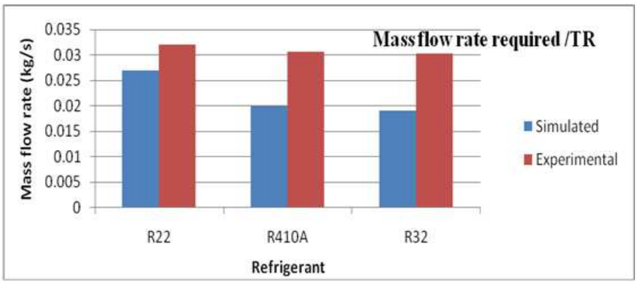

Figure 6. *Mass flow require per TR.*

Figure 5 shows the amount of mass flow required for 1 "Ton of Refrigeration" (TR) for the R32 required amount of mass flow rate is 0.0302 kg/s, R4410A is 0.0307 kg/s and R22 is 0.032 kg /s. For the same cooling capacity with compare to R22 and R410A refrigerants R32 is 5.6% and 4%is less.

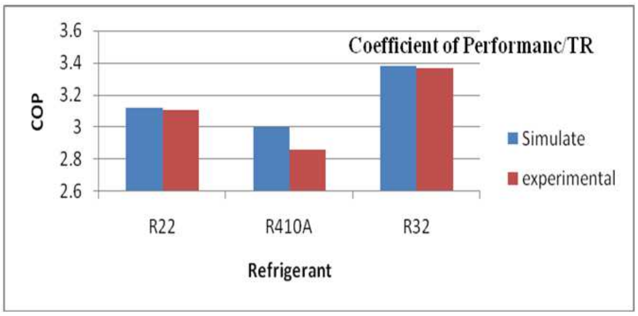

Figure 7. *COP of the selected refrigerants.*

The measured COP for the refrigerants are plotted and shown in figure 7 for condenser temperature of 54.5˚C and evaporator temperature of 7.2˚C, the R32 performs better than R410A.COP for R32 is 3 where as R410A COP is 2.89, consumption of power also low for R32 refrigerant. As R32 is having more refrigeration effect, the mass flows rate of refrigerant for R32 also less with compare to R410A.

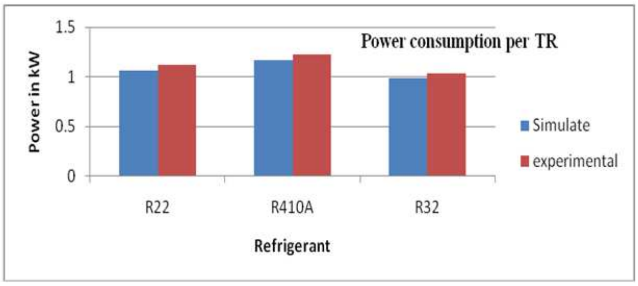

Figure 8. *Power Consumption for selected refrigerants.*

Figure 8 show the Power consumption for selected refrigerants for constant condenser and evaporator temperature i.e. Tc = 54.5˚C and Te = 7.2˚C. In all the cases the simulated power required is less than the experimental values. As per experimental analysis per 1 TR capacity the power consumption three refrigerants R22, R410A and R32 are 1.122kW, 1.225kW and 1.038 kW, with compare to R22 and R410A, the refrigerant R32 requires 7.84% and 15% less power.

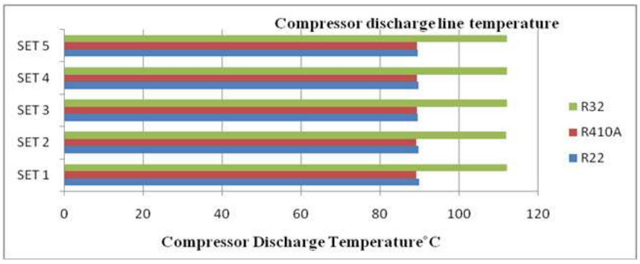

Figure 9. *Compressor discharge temperatures.*

From the figure 9 the discharge line temperature for R32 is 112˚C where as R22 is 89.7˚C and R410A is 99.3˚C, with compare to other two refrigerants R32 discharge temperature 19% and 12% higher. While designing the system it should be seen that the compressor discharge temperatures should not be exceed 130˚C.

5. Conclusions

1. R32 is the most balanced solution, not depleting the Ozone layer, smaller global warming compared to R410A.The global warming effect is 69 % and 61.7% less with compare to R410A and R22. It may be considered as alternative to R22 as well as 410A because environment friendly refrigerant.
2. An ideal refrigerant should have high latent heat of vaporisation which results higher refrigerating effect, hence coefficient of performance increases. R32 is having high latent heat i.e. 337 kJ/kg which is 36% higher than the R22.hence the advantage of this refrigerant is refrigerant effect is more per kg of refrigerant circulation in refrigeration cycle. The refrigerant R410A is having the latent of 238kJ/kg.
3. The refrigerant R32 possess higher pressure in both the cases i.e. suction and discharges pressures. The experimental suction and discharge pressures at evaporator temperature of 7.2˚C and condenser temperature of 54.5˚C, for R22 suction and discharge pressures 619.9 kPa and 2145 kPa. R410A suction and discharge pressures for 410A 988.4and 3387 kPa and for R32 the suction and discharge pressures are 1015.8 kPa and 3387 kPa.
4. From the experimental analysis per 1 TR capacity the power consumption three refrigerants R22, R410A and R32 are 1.122kW, 1.225kW and 1.038 kW, with compare to R22 and R410A, the refrigerant R32 requires 7.84% and 15% less power.
5. High compression ratio, consequently higher gas discharge gas temperature, if not controlled by proper system, may result in oil and refrigerant break down, forming carbon deposits on the valve plate which results choking of compressor.

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