ISSN 2229-5518

Theoretical Analysis and Performance Comparison of Different Alternative Refrigerants to HCFC-22

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Abstract--The main objective of this paper is to explore the possibility for developing new zero **ODP** (**Ozone Depletion Potential**) and low **GWP** (**Global Warming potential**) Alternate Refrigerants to R-22 in air conditioning application. In this study, the refrigerants like R290, R600a from HC group and R32 from Hydro Fluorocarbon refrigerant (HFCs) were selected and their performance was theoretically compared with (HCFCs) group Refrigerant R22.

Keywords: Alternate refrigerants, Hydrocarbon, Hydro chlorofluorocarbon**,** Hydro Fluorocarbon, and COP.

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1 INTRODUCTION

IN the last seven decades, the CFCs and HCFCs have been used in the field of refrigeration and air conditioning due to their favourable characteristics. As the significance of air conditioning for human comfort was considered as a luxury a few decades ago, but now in modern life it has become a necessary for every human being and for commercial purpose. The use of refrigerant has got more significance and HCFCs -22 is one of the important refrigerants in air conditioning all over the world [1]. The major disadvantage of R22 is ozone layer depletion and global warming effect, which causes lot of ill health and diseases for living and non living things. As per the agreement of Montreal and Kyoto protocol 1987 all CFC'S and HCFC'S must be phased out both in developed and developing countries. As per ASHRAE standard -34 all HCFC should be phased out by 2030 [2, 3].The Govt. of India, The Ministry of Environment and Forest (MoEF), emphasizing and giving indications on Environmental Impact Assessment (EIA).

2 LITERATURE STUDY

To search for alternative to refrigerant(HCFCs group) 22 A comprehensive literature study has been carried out for retrofit to existing vapour compression refrigeration system for various alternate refrigerants for both empirical and simulated results are studied [4], the basic performance and environmental parameters are

Ozone layer: Molina and Rowlands (1974) has been expanded into a comprehensive and very complex theory emphasis about 200 reactions that CFCs are significantly destroyed by UV radiation in the stratosphere. In the year 1987 Hoffman predicted 3 % global ozone depletion with contact of CFCs emissions of 700 thousand tone /year [4-5].

Montreal Protocol: the United Nations environment programme conference held in Montreal in September 1987 the decision taken to phase out ozone depleting substances (ODS) within a fixed time period is known as Montreal Protocol. Some of the feature of MP is as fallows. Developed countries will phase out CFCs by 1996.Developing countries will phase out CFCs by 2010 with freeze in 1999 and gradual reduction thereafter. Developed countries will phase out HCFCs by 2030 while developing countries have been provided a grace period of ten years i.e. phase out by 2040. Global warming is another serious issue. Some naturally occurring substances mainly cause this but CFCs have very large global warming potential. [6- 8].

3 GLOBAL WARMING

3.1 Kyoto protocol*:* the global warming issue was addressed by the third conference of parties to the United Nations framework convention **on climate change (UNFCCC) In December 1997** held at Kyoto. This is known as Kyoto protocol (KP). According to this, the developed countries of KP should reduce their average greenhouse gas emissions in aggregate by 5.2% below the 1990 levels within a period of 2008-2012.developing countries do not have any obligation under KP .In the year 1988 International Panel on Climate Change (IPCC) was established for scientific intergovernmental body to evaluate the risk of climate change caused by human activity. The IPCC provides the general accepted value for GWP, which changed slightly between1996 and 2001. The IPCC has predicted an average global rise in temperature of 1.4°C to 5.8°C between 1990 and 2100.

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3.2 Phase out schedule

Table 1 HCFC Phase out Schedule

HCFC	Phase out Schedule %
1996	100
2004	65
2010	35
2015	10
2020	5
2030	0

From the table 1, the phase-out of HCFCs uses a cap or limit, based on ozone depletion (ODP) unit concept. The base of the cap is determined via the following formula: **1989 CFC production X ODP X 2.8% +1989HCFC Production X ODP =Total ODP weighted cap.** Fig.1 and 2 shows, the levels of ozone depletion potential (**ODP**) and Global warming potential (**GWP**).

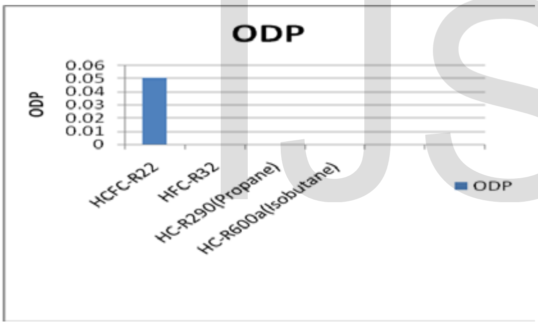

Fig.1 ODP levels for selected refrigerants

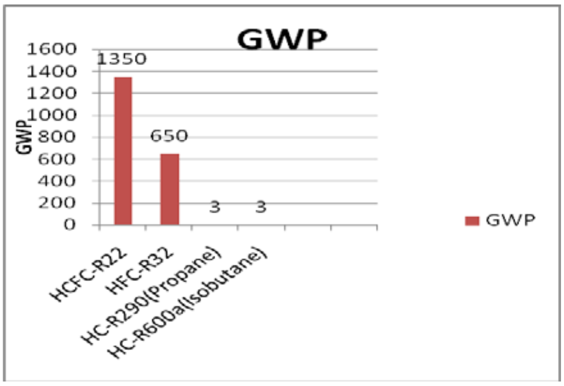

Fig.2 GWP levels for selected refrigerants

From the literature study, in selecting a refrigerant for a particular purpose its characteristic must be considered and the selection must be made on the basis of its compatibility with the system. [7,8].The desirable properties like Thermodynamic properties, Physical properties and Chemical Properties requires for high COP and safe to use while between different pressures

4. WORKING OF SIMPLE VAPOUR COMPRESSION REFRIGERATION CYCLE

The simple Vapour Compression Refrigeration cycle is shown in Fig.3. It consists of following four essential parts 1.Compressor, 2.Condenser, 3.Expansion Valve, and 4.Evaporator.

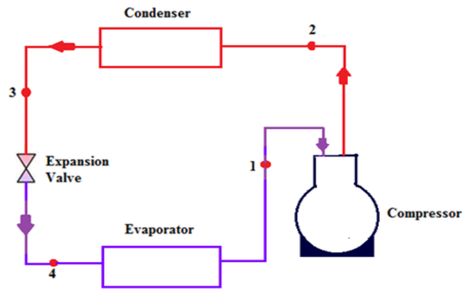

Fig.3 Simple Vapour Compression Refrigeration Cycle

Compressor compresses the vapour refrigerant to the condenser with high pressure and temperature , in the condenser condensation takes place by rejecting heat with cooling medium either water or air as a cooling medium the phase transfer takes place from vapour refrigerant to liquid refrigerant and enters into the Expansion Valve , the function of the expansion valve is to reduce the pressure from high condenser pressure to low evaporator pressure by throttling process, finally the liquid refrigerant enters in the Evaporator where cooling effect is produced by absorbing heat from the cooling space and only pure vapour enters into the compressor

4.1 Theoretical Cycle Analysis

The P-h diagram (Moeller diagram) shown in fig.4 is frequently used in the analysis of Vapour Compression Refrigeration cycle, the significant performance characteristics are Compressor work (Wc), Refrigeration Effect (Q_E) and Coefficient of Performance (COP).Process 1 to 2 is compression, 2 to 3 Condensation (Heat Rejection), 3 to 4 Expansion process (Throttling) and 4 to 1 Evaporation process (Heat absorption), the system performance is calculated as follows

$$COP = \frac{QE}{Wc} \quad (1)$$

$$Wc = m_r (h_2 - h_1) \quad (2)$$

$$QE = m_r (h_4 - h_1) \quad (3)$$

ISSN 2229-5518

$$\text{Pressure ratio (Pr)} = \frac{Pc}{Pe} \qquad (4)$$

$$\text{Power Required} = \frac{Wc}{60}\ \text{kW} \qquad (5)$$

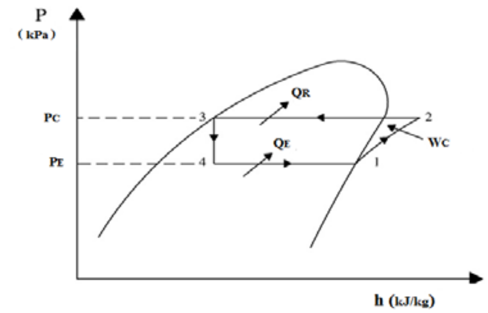

Fig.4.P, h Diagram for vapour compression refrigeration cycle

Where,

h_1 and h_2 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.

The evaporator pressure (P_E) should be positive and as near atmospheric as possible. If it is too low, it would result in large volume of the suction vapour. If it is too high, there exit overall high pressure in the system, which results for stronger equipment and higher cost.

5 PERFORMANCE COMPARISON OF REFRIGERANT:

Table 2 shows the theoretical comparison of refrigerant and their properties like molecular weight, chemical formula, Normal boiling point, Critical Temperature and Critical Pressures. R32 the critical temperature is very low, if the refrigeration cycle is operated near the critical temperature COP reduces, hence the refrigeration critical temperatures should be large.

Table 3 shows the performance parameters for selected refrigerants, In the Reversed Rankine Cycle the evaporator temperature is assumed to enter at -15°C (saturated vapour) and Condenser temperature is assumed as 30°C and 40°C, And their performance is compared.

Table 2: Refrigerants and their Properties

Refrigerant	**HCFC-R22**	**HFC-R32**	**HC-R290(Propane)**	**HC-R600a(Isobutene)**
Compression ratio (Pr) at Tc 30°C and Te -15°C	4.03	3.95	3.7	4.52
Compression ratio (Pr) at Tc 40°C and Te -15°C	4.06	5.08	4.64	5.92
COP atTc 30°C and Te -15°C	5.01	3.826	4.58	4.41
COP at Tc 40°C and Te-15°	3.387	3.8	3.785	4.18
Power consumption In hp per TR	1.011	2.29	1.031	1.07

Table 3.Performance of refrigerants

Refrigerant	**HCFC-R22**	**HFC-R32**	**HC-R290(Propane)**	**HC-R600a(Isobutene)**
Molecular weight	86.48	52.042	44.1	58.13
Chemical formula	$CHClF_2$	CH_2F_2	C_3H_8	$(CH_3)_3CH$
NBP°C	-40.9	-51.71	-42.07	-11.73
Critical Temp.°C	96	78.41	96.8	135
Critical pressure(bar)	49.74	58.3	42.54	36.45

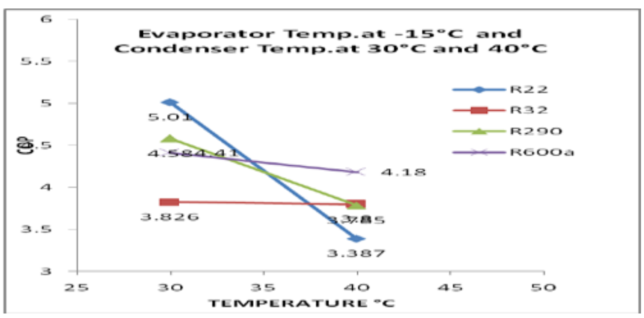

Fig.5.Variation of COP with ambient temperature

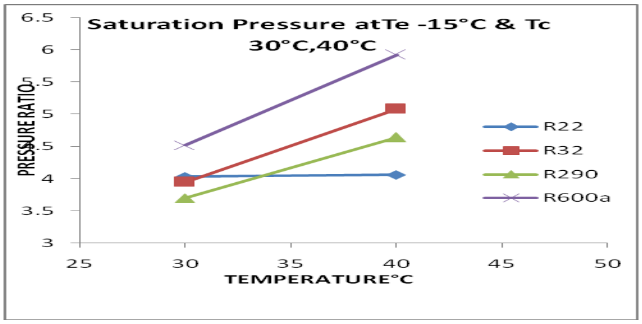

Fig .6. Variation of Pressure Ratio with ambient Temperature

From fig.5 to fig.7 shows the performance characteristics for different operating pressures and temperatures, as shown in fig.5 for the ambient conditions if the condenser temperature at 40°C COP for R600a is very high, where as R290 and R32 COP is closely matches, compare to HCFC22 all selected refrigerants gives better COP. Fig.6 shows the pressure ratio i.e saturation of evaporator at -15°C and condenser Pressure at 30°C and 40°C, R600a pressure ratio is high for higher pressure ratio the system cost will increase. From fig.7 Power consumption for R32 very high and R290 and R600a consumes nearly same power per TR.

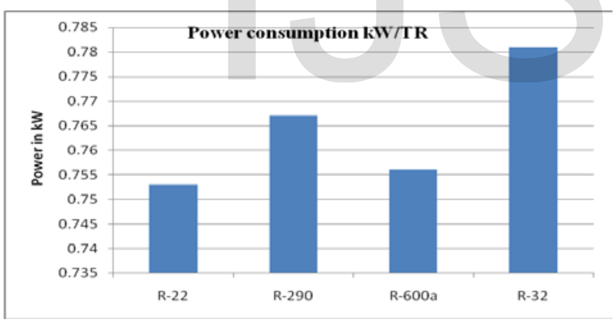

Fig.7 Power consumption for different refrigerants

6 CONCLUSIONS

R600a and R290 give better coefficient of Performance with low power consumption, R32 Consumes high power with compare to other refrigerants because, at higher ambient temperatures the pressure ratio is more. The advantage of R32 is very low flammability with compare to (HCs) R600a and R290. Hydrocarbons refrigerants have zero ODP and very small GWP. As they have Potential of better performance, they are being used in many countries now days. The only limitation with Hydrocarbon refrigerants is they are flammable; hence the safety issues must be addressed in terms of Manufacturing, handling, storage and servicing. The HFCs are transitional compounds substitutes with low ODP, but, these will also have to be replaces. The hydrogen atom causes hydrolysis and also having GWP, hence these are also uncertain candidates in near future .To prevent the environmental damage and to reduce the harmful effects the refrigeration industry must shift towards the natural refrigerants.

ACKNOWLEDGEMENT

1. This research work has been carried out under O.U/D.S.T-PURSE Programme, Scheme no A-38, Department of mechanical engineering, University College of Engineering, Osmania University.
2. The experiment is studied and conducted At Tecumseh products India Pvt.Ltd., Balanagar, Hyderabad.

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