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Research Article

# Simulation of Air-Conditioning Compressor with Different Refrigerants and to Retrofit in Existing (HCFCs-22) Air-Conditioning Systems

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***Abstract***

*This paper presents the different characteristics of Ozone Friendly Hydro fluorocarbon refrigerants (HFCs) group refrigerant i.e. R32 and R410A in vapour compression refrigeration system. The performance parameters were simulated with available experimental data of R22 and R410A (near azeotrope) mixture refrigerant with 1.565 'TR' (Ton of Refrigeration) capacity, by using REFPROP and cool pack simulation tool. For simulation the evaporator operating temperatures from -10°C to +10°C and condenser temperature from 35 °C to 60°C was considered. With compare to R22 and R410A refrigerants, the refrigerant R32 yield better Coefficient of Performance at higher ambient temperatures.R32 is emerging in the refrigeration market because of its better energy efficiency and environmental friendly refrigerant. The atmospheric life for R22 is 15 years and for R32 is 4.9 years hence R32 has been accepted as safety group refrigerant under the class A2L ASHARE standers.*


***Keywords:*** *Ton of Refrigeration, Hydro Fluorocarbon, ODP, GWP and Coefficient of Performance*

## 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 (Devotta,S, Padalkarans A.S, Sane N.K 2013). The major disadvantage of R22 is having ozone layer depletion potential 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(ASHRAE, HVAC Hand Book).The Govt. of India, The Ministry of Environment and Forest (MoEF), emphasizing and giving indications on Environmental Impact Assessment (EIA). The Ministry has issued the Environmental Impact Assessment Notification, 2006, which makes environmental clearance mandatory for the development activities to identify, examine, assess and evaluate the likely and probable impacts of a proposed project (alternate refrigerants) on the environment and thereby, to work out remedial action plans to minimize adverse impact on the environment. R32 is emerging in the field of Refrigeration and Air-Conditioning Systems as Zero Ozone Depletion Potential and low Global warming Potential and favourable performance with less environmental.

## 2. Literature Review

To search for( HCFCs group) alternative to refrigerant 22 A comprehensive literature study has been carried out for retrofit refrigerants in existing vapour compression refrigeration system for various alternate refrigerants for both empirical and simulated resulted are studied (B.O.Bolaji, M.A. AkintundeandT.O.Falade, 2011) , the basic performance and environmental parameters are in terms of following important aspects. Molina and Rowland's (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 ( Azizuddin ,2010),

### *2.1. Ozone layer*

**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

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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. (BukolaOlalekanBolaji, 2010).

*2.2. Global Warming*

**Kyoto protocol***:* the global warming issue was addressed by the thirdconference of partiesto the United Nations framework conventio**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 and2100.

**Table 1** Present Trends of Refrigerants

| Group | Name |
|---|---|
| HC | Hydrocarbons |
| FC | Fluorocarbons |
| HFC | Hydro fluorocarbons |
| HCFC | Hydro chlorofluorocarbons |

After the finding the environmental effects of CFCs and the lesser extent of HCFCs group refrigerants as depleting the Ozone Layer as to phase-out CFCs and HCFCs in the year 2000 and 2030. The new trends to use the alternate refrigerants are shown in table 1

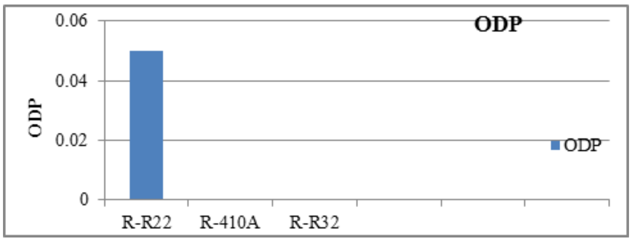


**Figure 1** ODP levels for selected refrigerants

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.( R.C. ARORA , 2009) .The desirable properties like Thermodynamic properties, Physical properties and Chemical Properties requires for good COP and safe to use while between different pressures and the figures 1&2 show the different levels of ODP and GWP of selected refrigerants.

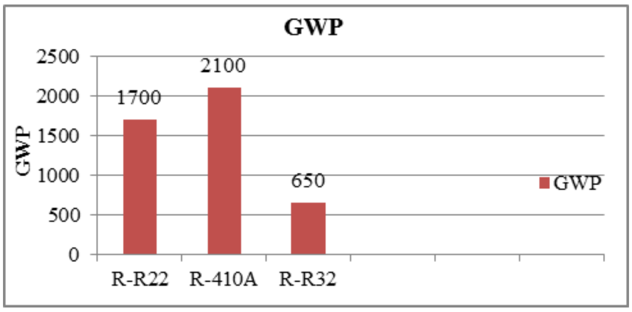


**Figure 2** GWP levels for selected refrigerants

**3. Simple vapour compression refrigeration cycle**

The simple Vapour Compression Refrigeration cycle is shown in Figure.3. It consists of following four essential parts 1.Compressor, 2.Condenser, 3.Expansion Valve, and 4.Evaporator. Compressor compresses the vapour refrigerant to the condenser with high pressure and temperature , in the condenser condensation takes place by rejecting heat in the form of latent heat of condensation with cooling medium of either water or air hence 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.

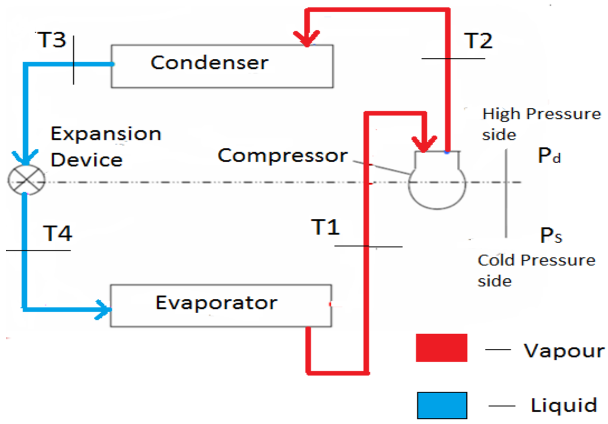


**Figure 3**Vapour compression refrigeration cycle

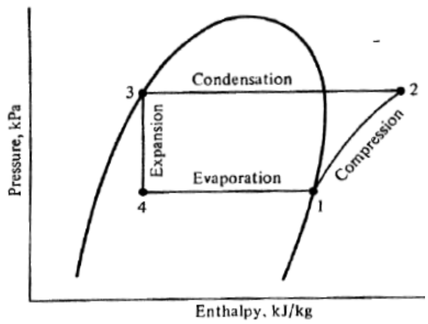


**Figure 4.**P, h Diagram for refrigeration cycle

### *3.1. Theoretical Cycle Analysis*

As shown in figure 4,The P-h diagram (Moeller diagram) for refrigeration cycle 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 4to 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).The Performance of a Refrigerator is expressed by the ratio of amount of heat taken by the cold body to the amount of work supplied by the compressor, this ratio is called Coefficient of performance. The system performance is calculated as follows.

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

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

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

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

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

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).

## 4. Simulation analysis

For simulation, REFPROP version 6.01 (REFPROPis an acronym for **Ref**rigerant **Prop**erties) used for finding out the properties of Refrigerant 32, which gives the most accurate pure fluid property for simulation, developed by the National Institute of Standards and Technology (NIST) provides the thermodynamic and transport properties of refrigerants (REFPROPversion 6.01, 2001). REFPROP also provides high accuracy data for pure refrigerants and refrigerant mixtures.

### *4.1Cool Pack (Version 1.49)*

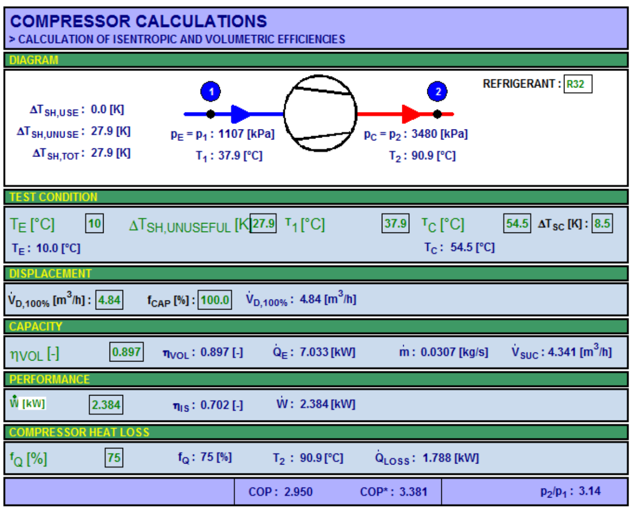


**Figure 5** Simulation of Air conditioning Compressor

**The cool pack** is a collection of simulation programs used for designing, dimensioning, analyzing and optimizing the refrigeration system. The system simulation is carried out for R32 and R410A refrigerants and shown in figure 5, simulated results of R32 thus obtained are compared with the available experimental test data of R22, the performance parameters like power consumption, Coefficient of Performance and Pressure ratios are compared. The Programs in cool pack covers following simulation purpose:

- Calculation of Refrigeration Properties (Property plots, thermodynamic and Thermo-physical data, Refrigerant Comparisons.
- Cycle Analysis –Compression of single Stage and Multi Stage.
- System dimensioning-Calculation of component sizes from general configuration criteria.
- System Simulation-Calculation Operating conditions in a system with known components with their operating parameters.
- Evaluation of Operation-Evaluation of the system Coefficient of Performance with less power consumption.

## 5. Results and discussion

From the above simulated results of selected refrigerants the following results were analyzed and compared to different performance parameters like COP, Cooling capacity and mass flow rate. Table 2 shows the theoretical comparison of refrigerant R32, R41A and R22 of various properties and Performance parameters affecting COP for air conditioning system. In the Refrigeration 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 tabulated. R32 COP is high and for R410A COP is 2.94, whereas R22 COP is 2.08 at higher condenser Temperature i.e. higher ambient conditions.

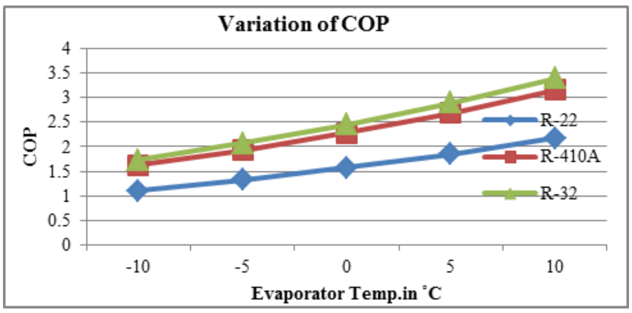


**Figure 6** Variation of COP with evaporator

From the figures 6 to 8 shows the performance characteristics for selected Refrigerants. As shown in figure 6 As per Indian scenario for ambient conditions if the condenser temperature at 40°C, Coefficient of Performance for Refrigerant 32 is 3.402, R410A is 3.151 and COP for R22 is3.07 i.e. 9.55% more. Figure 7, shows that the mass flow rate required for Refrigerant 32 is 41% less with compare to R22; the mass flow rate required for

**Table 2:** Comparison of simulated results

| Tc(°C) | Te(°C) | C.O.P | | | Cooling capacity(kW) | | | Maas flow (kg/s) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | R-22 | R-410A | R-32 | R-22 | R-410A | R-32 | R-22 | R-10A | R-32 |
| 35 | -10 | 1.27 | 1.93 | 2 | 2.737 | 4.059 | 4.32 | 0.015 | 0.021 | 0.0151 |
| | 0 | 1.8 | 2.73 | 2.8 | 3.86 | 5.64 | 6.05 | 0.022 | 0.030 | 0.022 |
| | 10 | 2.5 | 3.7 | 3.8 | 5.3 | 7.67 | 8.2 | 0.030 | 0.042 | 0.0307 |
| 40 | -10 | 1.22 | 1.86 | 1.9 | 2.64 | 3.89 | 4.16 | 0.015 | 0.021 | 0.0151 |
| | 0 | 1.75 | 2.62 | 2.71 | 3.72 | 5.4 | 5.83 | 0.0215 | 0.029 | 0.022 |
| | 10 | 2.42 | 3.6 | 3.76 | 5.135 | 7.3 | 7.9 | 0.0302 | 0.042 | 0.0307 |
| 45 | -10 | 1.189 | 1.78 | 1.85 | 2.544 | 3.7 | 4.04 | 0.015 | 0.0208 | 0.0151 |
| | 0 | 1.68 | 2.51 | 2.62 | 3.589 | 5.15 | 5.61 | 0.0215 | 0.0298 | 0.0217 |
| | 10 | 2.33 | 3.46 | 3.63 | 4.93 | 6.94 | 7.6 | 0.0302 | 0.042 | 0.0307 |
| 50 | -10 | 1.15 | 1.7 | 1.79 | 2.44 | 3.5 | 3.86 | 0.015 | 0.0208 | 0.0151 |
| | 0 | 1.62 | 2.4 | 2.53 | 3.447 | 4.87 | 5.39 | 0.0215 | 0.0298 | 0.022 |
| | 10 | 2.254 | 3.3 | 3.5 | 4.73 | 6.56 | 7.3 | 0.0302 | 0.042 | 0.0307 |
| 55 | -10 | 1.104 | 1.62 | 1.27 | 2.343 | 3.31 | 3.71 | 0.015 | 0.0208 | 0.0151 |
| | 0 | 1.56 | 2.27 | 2.43 | 3.3 | 4.58 | 5.16 | 0.0215 | 0.0298 | 0.0217 |
| | 10 | 2.16 | 3.134 | 3.367 | 4.53 | 6.146 | 7 | 0.0302 | 0.0422 | 0.0307 |
| 60 | -10 | 1.06 | 1.52 | 1.166 | 2.23 | 3.01 | 3.54 | 0.015 | 0.0208 | 0.0151 |
| | 0 | 1.52 | 2,14 | 2.33 | 3.15 | 4.3 | 4.9 | 0.0215 | 0.0298 | 0.0151 |
| | 10 | 2.08 | 2.94 | 3.22 | 4.32 | 5.69 | 6.66 | 0.0302 | 0.0422 | 0.0307 |

R410A is 0.0422kg/s which are very high with compare to other two refrigerants.

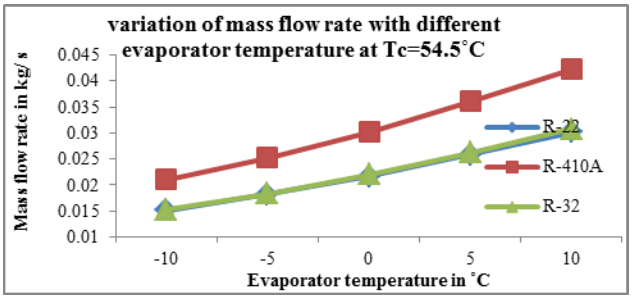


**Figure 7** Mass flow rate in kg/s at Te -15°C and Tc 40°C

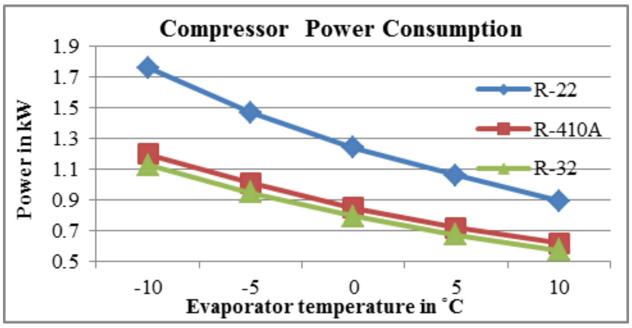


**Figure 8** Power consumption for different refrigerants

As R32 is having less mass flow rate, there will be less loads on to the compressor with minimum energy (power) required for compression processes, this will be advantageous for eco-friendly refrigeration cycle. Figure 8, shows the power consumption for 1.565Ton capacity, the power consumption of selected refrigerants with the decrease in evaporator temperature, the work of compressor increases and mass of refrigerant circulated per minute decreases which results in increase of compressor power it is observed from the simulation for different refrigerants that the power consumption for refrigerant 22 is very high where as R32 and R410A consumes low power for fixed condenser temperature and for different evaporating temperatures.R22 requires 0.8976 kW of power , R32 0.575 kW and R410A refrigerants requires 0.61 kW per TR.

## Conclusions

The following conclusions have been drawn for the selected refrigerants of ozone –friendly Hydro fluorocarbon (HFC) Refrigerant R32 is simulated results with R22 experimental data.

1).The HFCs group refrigerants (R32) emerging transitional compounds toward refrigeration and Air –Conditioning, because they are ozone –friendly i.e. Zero Ozone Depletion Potential (ODP) and having 650 Global Warming Potential (GWP) which slow compare to R22.

2).R32 yields higher COP at higher ambient conditions (Indian scenario i.e. ambient temperature in Summer will be about 50°C ), for Condensing Temperature at 40°C the COP is 3.402 and 3.077 for R22 which is 9.55% more.

3).The mass flow rate required for Refrigerant 32 is less with compare to R22 i.e. 41% less, the mass flow rate of R410 is very high i.e. 0.0422 kg/s. The Power consumption for R32 is less with compare to R22. R32 has identified as safety group classification A2 by ASHARAE.

4).Major advantages and benefits of R-32 is better efficiency in peak power under cooling condition with less risk. To prevent the environmental damage and to reduce the harmful refrigerants usage, there is a need of refrigeration industry to shift towards the HFC32; however it needs further improvement to become practical.

## Acknowledgement

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2. The experiment is studied and conducted At Tecumseh products India Pvt.Ltd., Balanagar, Hyderabad.

## References

Devotta,S, Padalkar and A.S, Sane N.K (2013) Experimental Performance Analysis of a Retrofitted Window Air Conditioner with R-407CInternational Refrigeration and air conditioning confrrence.Paper May 2013, PP533.

ASHRAE, Thermo physical Properties of Refrigerants Chapter 20, ASHRAE Fundamentals.

HVAC Handbook-2007 Indian Society of Heating Refrigerating and Air – Conditioning Engineers, Part I-Air Conditioning.

B.O.Bolaji, M.A. AkintundeandT.O.Falade, (2011) Comparative Analysis of Performance of three Ozone- Friends HFC Refrigerants in a Vapour Compression Refrigerator, Journal of Sustainable Energy &Environment 2 61-64.

Azizuddin (2010), on Alternate Refrigerants for Air Conditioning , PhD. Theses, Osmania University , India.

BukolaOlalekanBolaji (2010),Effect of Sub-Cooling on the Performance of R12 Alternatives in Domestic Refrigeration system, ThammasatInt.J.Sc.Tech., Vol.15,pp.12-19.

R.C. ARORA, Refrigeration and Air Conditioning Book by Refrigeration and Air Conditioning, Dhanpatrai publications, India,2009.

REFPROPversion 6.01 AND Cool Pack Version 1.49 Refrigeration and *Air Conditioning Simulation tool.*