SIMULATION OF AIR- CONDITIONING SYSTEM COMPONENTS AND COMPARISON OF PERFORMANCE FOR THREE DIFFERENT REFRIGERANTS

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Abstract-This paper presents the simulation study of three different refrigerants i.e. R22, R410A and R32 in vapour compression refrigeration system. The available experimental data of R22 was used for air conditioning system capacity of 1.565 'TR' (Ton of Refrigeration) .For system simulations the REFPROP and cool pack simulation tool was used. The main objective of selecting theR32 and R410A is to explore the possibility of developing new zero ODP and very low GWP refrigerants an alternative to R22. R22 is HCFC group refrigerant with 0.05 ODP and 1700GWP and R410A with Zero ODP and 2100 GWP which are responsible for environmental impacts. World community has decided to phase-out such refrigerants. R32 is having zero ODP and Very low GWP (650). For simulation, the range of evaporator temperatures was considered from -10°C to +10°C and condenser temperature from 35 °C to 65°C. With compare to R22 and R410A refrigerants, the refrigerant R32 yields better coefficient of performance (COP) at higher ambient temperatures.R32 is rising in the refrigeration market because of its better energy efficiency and environmental friendly. 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

Air conditioning is a process of simultaneous control of temperature, humidity, flow of air and cleanliness of air. In olden days the air conditioning was treated as luxury but now days it has become part and parcel of human being. The use of refrigerant has got more significance and HCFCs -22 is one of the important refrigerants in air conditioning all over the world, S.Devotta et al [1],explained the studies related to the alternative refrigerants. 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[2&3].

2. LITERATURE REVIEW

To search for (HCFCs group) alternative to refrigerant 22 A comprehensive literature studies 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, et al. [4]. 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 Hung Pham, [5] described about the Total Equivalent Worming Index (TEWI), which takes the account of both indirect and direct impact of global warming agents resulting from the energy consumption of the system. From the vast literature studies the facts reveals that HFCs can be seen in many cases to offer the best alternative to HCFCs group refrigerants. By encouraging government-industry partnerships and existing voluntary efforts towards the effective use of containment, recovery and recycling of HFCs, the present potential global warming impact by use of these products can be minimized. 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. 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 [6&7]. 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.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 [8] .The desirable properties like Thermodynamic properties, Physical properties and Chemical Properties requires for good COP and safe to use while between different pressures

3. Air Conditioning System

A window air conditioner is basically an enclosed assembly designed to be a compact unit primarily for mounting in a window, through the wall. Fig 1 shows the block diagram of air-conditioning system the function of a window mounted room air conditioner is to provide comfort to occupants in the room by circulating clean, cool air. A complete unit of room air conditioner consists of the refrigeration system, the control system, electrical system, air circulation system ventilation and exhaust system. The basic functions of a window air condition system are, Compressor which pumps up the low pressure refrigerant from the evaporator to the condenser as super heated vapour at high pressure. Evaporator is an important device used in low pressure side of the refrigeration system. Evaporator in which, the heat from the room air is absorbed by the circulating refrigerant. Condenser in which the refrigerant rejects heat to the atmosphere, absorbed in the evaporator. The phase transfer takes place in the condenser i.e. superheated vapour refrigerant to liquid refrigerant. Air cooled condenser are generally used. It consists of copper tubing through the refrigerant flows. Capillary tube in which, the refrigerant throttles from high pressure liquid to low pressure liquid. Single phase double-ended shaft fan motor on to which impeller and propeller are fitted which draw air onto evaporator and condenser. An air filters which arrests dust from air entering the evaporator. Damper controls for fresh air ventilation and room air exhaust. A set of sheet metal components with thermal insulation wherever necessary. Control panel equipped with controls for operating the unit which includes a room air temperature control device.

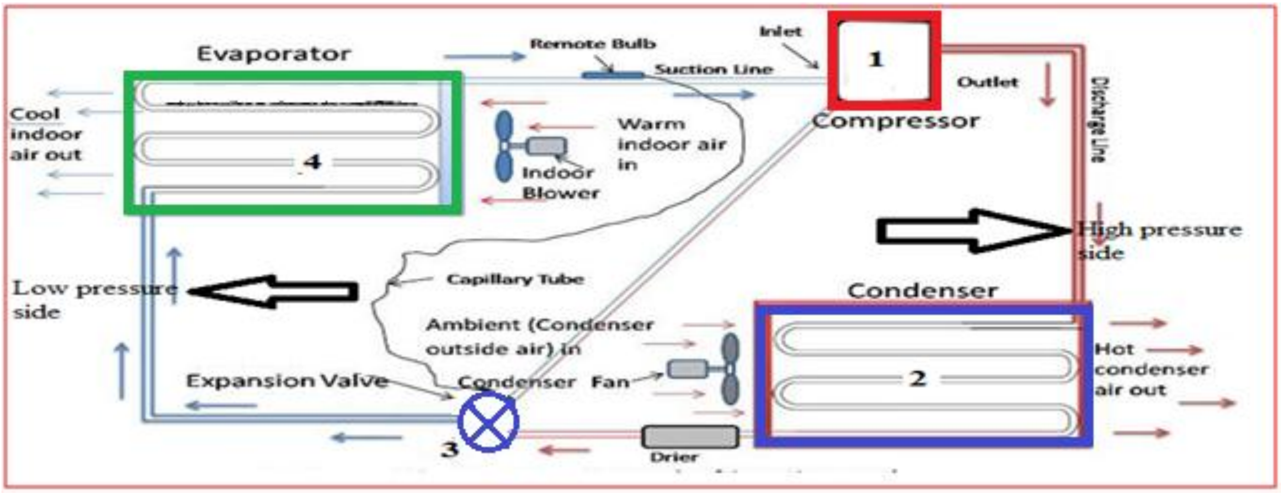

Fig .1 Block diagram of air conditioning system

3.1. Theoretical Cycle Analysis

The simple Vapour Compression Refrigeration cycle 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.

Fig.2 shows 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

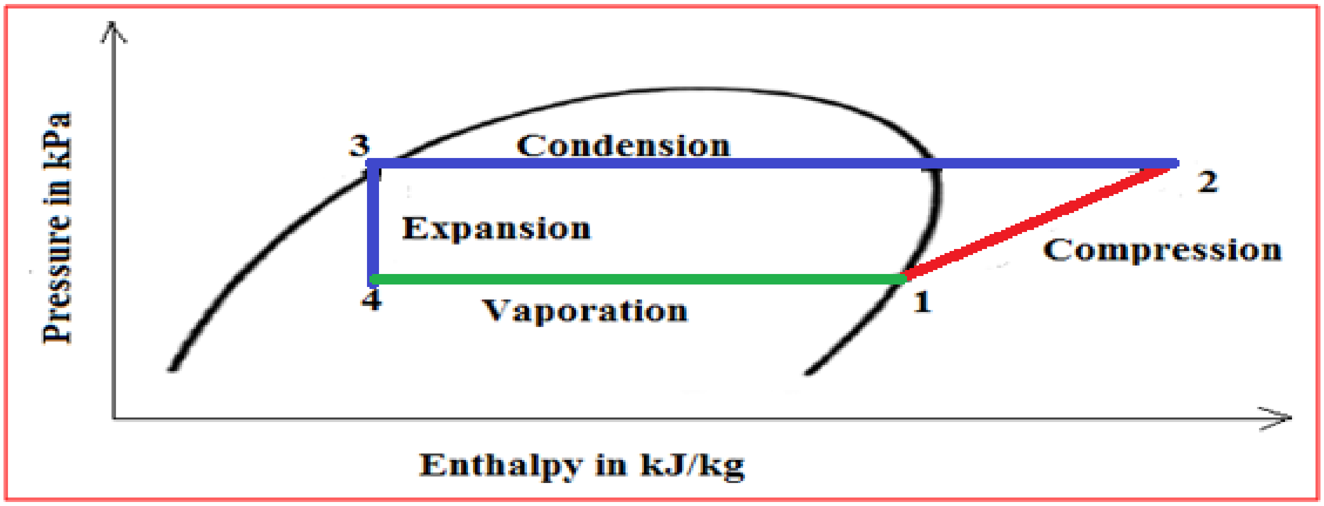

Fig.2 p-h diagram of single stage vapour compression cycle

4. SIMULATION OF VAPOUR COMPRESSION CYCLE

For simulation, REFPROP version 6.01 (REFPROP is an acronym for Refrigerant Properties) used for finding out the properties of R32, 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 [9-10].REFPROP also provides high accuracy data for pure refrigerants and refrigerant mixtures. The cool pack is a collection of simulation programs used for designing, dimensioning, analyzing and optimizing the refrigeration system.

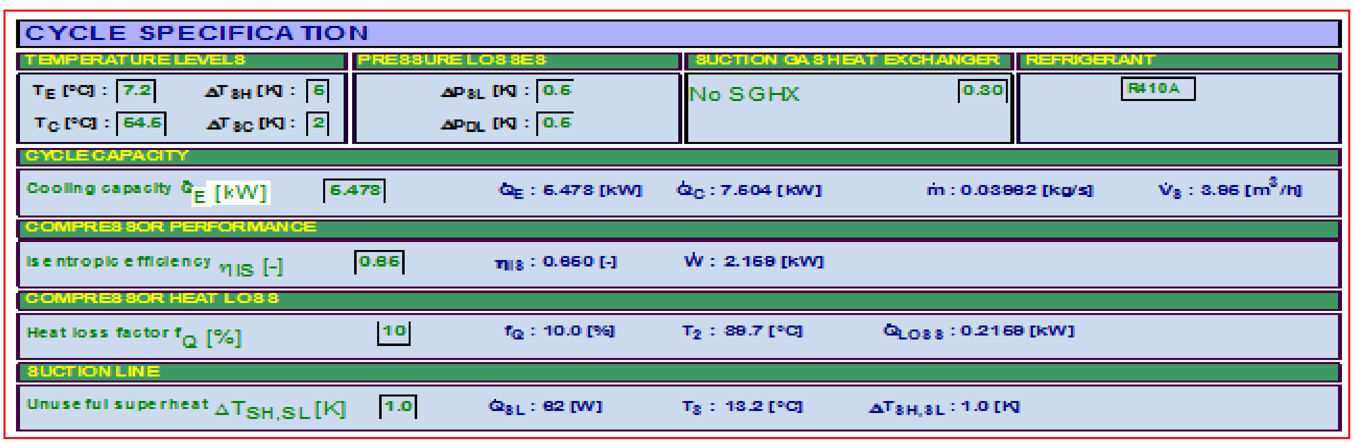

Fig 3. Simulation of air conditioning parameters

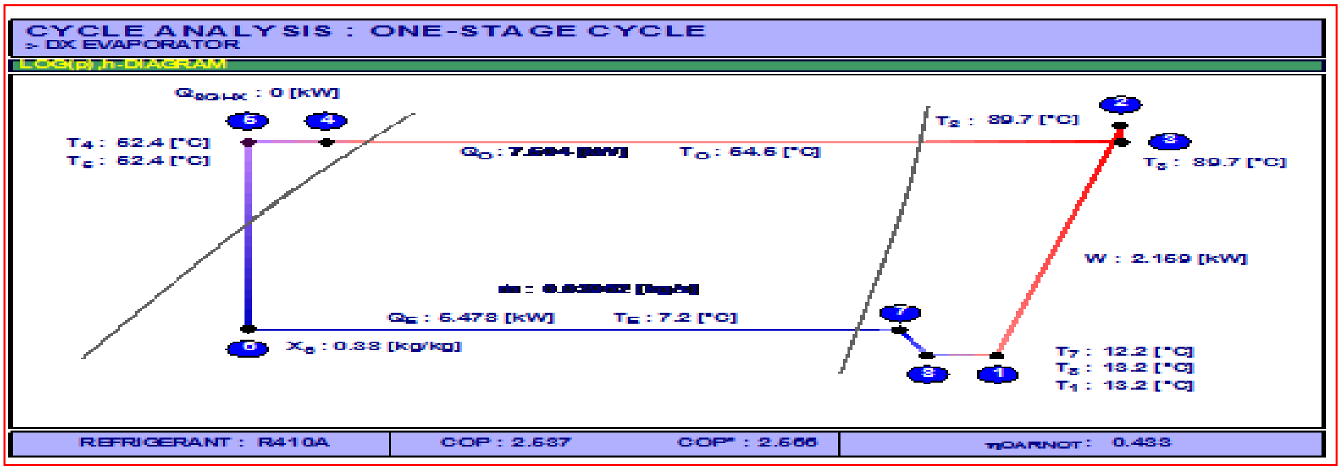

Fig. 4 Simulation of Air conditioning Cycle

The system simulation is carried out for selected three refrigerants thus obtained are compared with the available experimental test data of R22, the performance parameters like power consumption, Coefficient of Performance and Pressure ratios and mass flow rate are compared for the evaporator temperature from -10°C to 10˚C and Condenser Temperature from 35°C to 65˚C[11-14]. Fig. 3 & 4 shows simple vapour compression cycle specification and simulation parameters.

5. RESULTS AND DISCUSSION

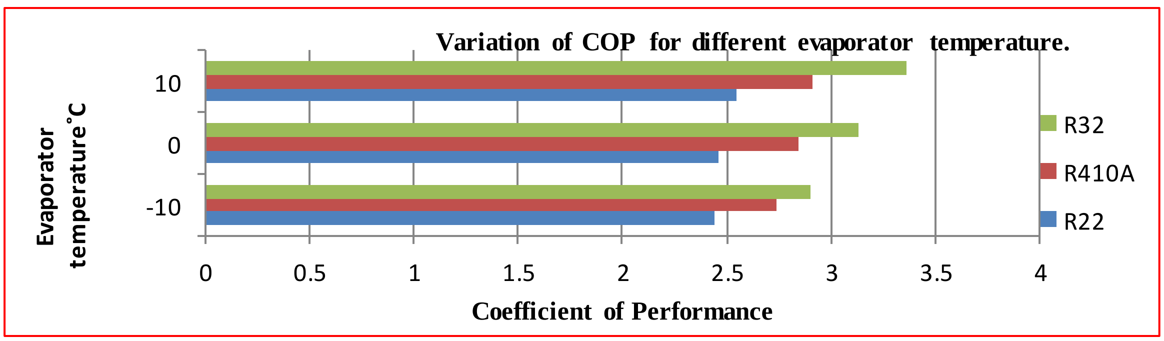

Fig.5 Variation of COP with evaporator temperature.

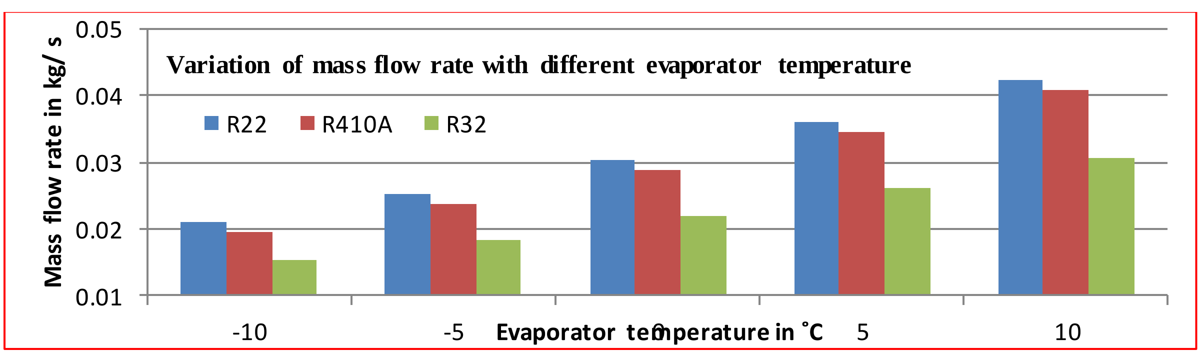

Fig. 6 Mass flow rate for selected refrigerants

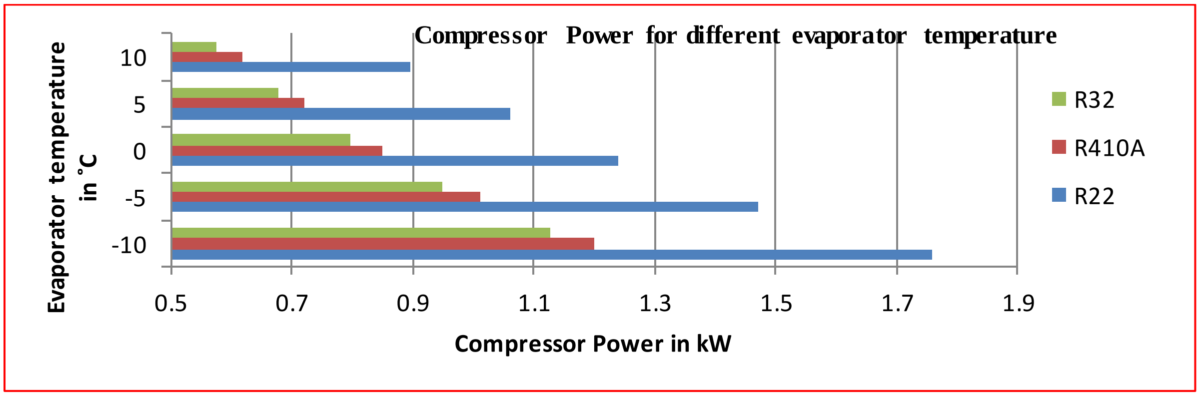

Fig. 7 Power consumption for different refrigerants

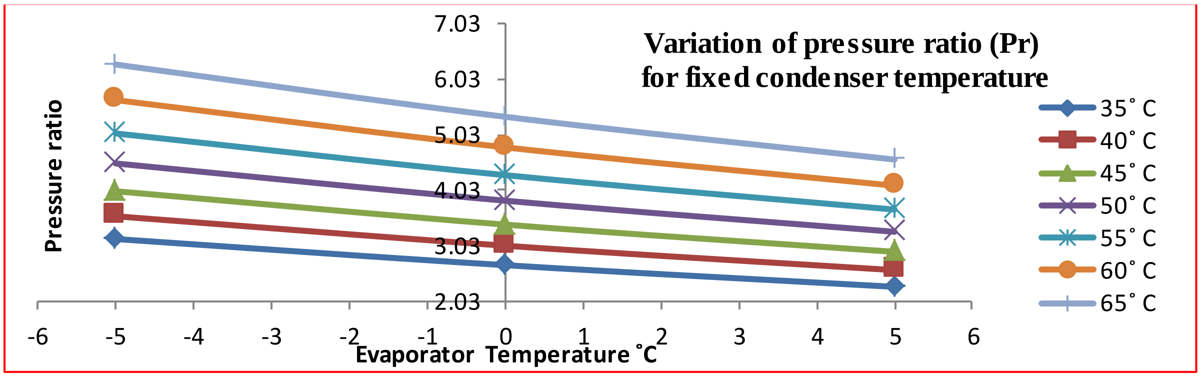

Fig. 8 Pressure ratio for selected refrigerants

From fig. 5 to 8 shows the performance characteristics for selected Refrigerants for the given input parameters and obtained output parameters are analyzed and their performance like COP, Mass flow rate and power consumption are compared. As shown in Fig. 5 for high ambient conditions if the condenser temperature at 55°C and evaporator temperature of 10˚C, Coefficient of Performance for Refrigerant 32 is 3.37, R410A is 3 and COP for R22 is 2.55. Fig. 6 shows the mass flow rate required, for evaporator temp of -10 ˚C and condenser temperature 55˚C R32 requires 0.01537kg/s, R22 requires 0.021 kg/s and for R410A requires 0.0196kg/s. With compare to R22 and R410A refrigerants, 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. Fig. 7, 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". Fig. 8 shows the variation of pressure ratios for different condenser and evaporator temperatures for the fixed condenser temperature of 65˚C and for the evaporator temperature of -5˚C the pressure ratio obtained was 6.29.In all the cases the pressure ratio decreases for fixed condenser temperature and for the evaporator temperature of -5˚C to +5˚C. The pressure should be moderate for a given operating conditions.

6. CONCLUSIONS

The following conclusions have been drawn from the simulated results of selected refrigerants.

- R32 is environmental free refrigerant which can be used in the refrigeration and air conditioning applications, because of **zero** Ozone Depletion Potential (ODP) and having 650 Global Warming Potential (GWP) which is low with compare to R22.
- For high ambient conditions if the condenser temperature at 55°C and evaporator temperature of 10˚C, Coefficient of Performance for Refrigerant 32 is 3.37, R410A is 3 and COP for R22 is 2.55.When compare to R22 and R410A, the R32 COP is 24% and 11% more. The mass flow rate required for Refrigerant 32 is less.
- The air conditioning system with fixed condenser temperature and for different evaporating temperatures. The power required for R22 is 0.8976 kW, R32 0.575 kW and R410A 0.61 kW per one "TR" capacity.
- The variation Pressure ratio is the ratio of absolute discharge pressure to the absolute suction pressure, the absolute discharge pressure is always more than the absolute suction pressure, and hence the pressure ratio is always more than unity for the fixed condenser temperature of 65˚C and for the evaporator temperature of -5˚C the pressure ratio obtained was 6.29.
- AS per ASHRAE standards R32 (Difluoro methane) has been identified as A2L safety group refrigerant.

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