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Experimental investigation on the performance of air conditioner using R32 Refrigerant

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Abstract: *This paper exhibits two approaches of refrigerant comparison for the retrofitting process in 1.5 ton capacity room air conditioning system. One is experimentation that was conducted for selected refrigerants using air conditioner test rig and calculate cycle performance analysis, another one is the simulation process by utilizing software like ASPENONE (aspen V8). With this software we can simulate the cyclic process of VCR system to work out the thermo physical properties of three refrigerants R22, R134a, and R32.The performance parameters includes the real coefficient of performance, mass flow rate, and power passed to the compressor. Under the class A2L ASHARE standers R32 has been accepted as safety group refrigerant because the atmospheric life for R22 is 15 years and for R32 is 4.9 years. By taking these performance results and simulation results the R32 is the efficient refrigerant for the retrofitting of an air conditioning system.*
Keywords: *Refrigerant, global warming potential, ozone depletion potential, Retrofitting process, and Simulation analysis.*

I. Introduction

Previously the air conditioning for human comfort was considered a luxury in most of the countries at present it is a necessity, therefore air conditioning industry is growing rapidly throughout the Earth. Due to increase in population and industrialization the uncomforting may be ascribable to the short provision of oxygen or unbearable temperature. The use of air conditioning is to furnish a sufficient mass of clean air containing a specific sum of water vapor and at a temperature capable of maintaining predetermined atmospheric conditions. Basically the air-conditioner is working along the principle of vapor compression refrigeration system in this process the refrigerant plays a significant part. The refrigerant is a volume of fluid substance. Which contain 'chlorine' atom in their molecules referred to as chloro-fluoro-carbon (halo carbons), in place of chlorine atom hydrogen is present in their molecules referred to as hydro fluorocarbon (HFC). Chlorine and fluorine atoms are not present in the refrigerant is referred to as the hydrocarbons (HC), fluorine atom in the molecule of refrigerant makes them physiologically more favorable and chlorine atom leads to ODP. The usage of these refrigerants concerns about environmental issues like global warming potential and ozone depletion potential. The selection of R32 refrigerant is based on their required properties [1]. It is an HFC that is already widely used as a component in many existing refrigerant blends including R407 series, r410A, R427A, R438A, R442A and R449A. However the use of pure R32 is gaining momentum, as the drive for high energy efficiency and low environmental impact refrigerant increases. This zero ODP and lower GWP (only 675) alternative provides substantial environmental benefit which also providing additional advantages such as lower system charge sizes and high efficiency versus R410A. The R32 is especially suited for usage in applications that historically have used R22.

II. Review of the literature

This survey was investigated on alternative refrigerants for the vapor compression refrigeration system because of the phase out of R134a and the selection process of refrigerants was depends on availability, environmental-friendly. Piotr a. Domanski et al [1] evaluated the performance of R600a, R290, R134a, R22, R410A, and R32 in an optimized VCR system used for comfort cooling applications. Based on thermodynamic properties only a theoretical cycle analysis is done for ranking of different refrigerants in that R32 and R290 having a highest system COPs. In order to put air-conditioning equipment on the market the refrigerant selection process is a preliminary step for a given cost that includes life cycle climate performance. B. Hadya et al. [2] conduct an experiment on comparative study of eco-friendly refrigerants in a lower capacity air-conditioning system in between three different refrigerants. Now-a-days hydrocarbons are used in many states and the coefficient of performance of R290 is nearly equal to the R22 but the sole limitation is until they are inflammable. The primary advantage of the R32 is they are experiencing very low flammability nature in the surroundings. M.Ashok Chakravarthy et al [2] look into an alternative refrigerant for R22 in air-conditioning system. There are two refrigerants R407C and R407A showed a significant performance in C.O.P, similarly in cooling capacity also they were good refrigerants. It yields a significant growth in energy efficiency rate respectively. R. Propane [3] et al works with potential refrigerants for retrofit process through simulation. The refrigerant comparison process is done in two approaches one is to find out the thermo-physical properties and cycle performance analysis, the second approach is full simulation. Some common refrigerants like R32, R410A, R134a, R600a, R125, R1270, R22, R407C, R290, and R600 their thermo-physical properties are taken from the refprop7.0 not including global warming potential. In lodge to obtain the original operation and/or capacity for different refrigerants in retrofitting process need to vary the existing heat exchangers and compressor. B.O. Bolaji et al. [4] Had done a performance analysis in a vapor compression refrigerator using three ozone-friends refrigerants. The experimental operation and comparison were done in between the different refrigerants among those the R152a having zero ODP and very low global warming potential. In terms of coefficient of performance and ozone friendly parameters R152a better performed then the R134a. Abhishek Kumar [5] conduct a survey on flow of various alternative refrigerants in Air conditioner it works on which is the best replacement for the R22 and which is the better possibility to increase the functioning. Buckle Olalekan Bolaji et al [6] conduct a trial to ascertain out the best alternative refrigerant for R134a in the vapor compression refrigeration system. The considered eco-friendly refrigerants are R600a and R152a. Among all the investigated refrigerants R152a is the most energy efficient refrigerants and having the average COP of 13.4% higher than that of R134a. Not only in COP but also R152a has the highest thermal conductivity lowest power per ton of refrigeration and high refrigerating effect, then compare to the R600a so it was the best reliever for the VCR system. S.k. kalla et al [7] studies shows that replacement refrigerants for VCR system, in place of CFC12 the mixer of HC290/HC600a (40/60 by weight. %) and in place of CFC22 the mixer of HC290/HC1270 (20/80 by weight. %) is utilized. The proportions are considered for reduction of emission of green house gases. Gaurav et al [8] search for an alternative to R134a refrigerant, based on thermodynamic properties R32, R152a, R125, R413A (mixture of 88% R134a, 9%R218,3%R600a), R290/R600a (68/32 by weight. %), R290/R 600a (40/60 by wt. %) and R123/R290(mixture of 7/3) are the suitable retrofit refrigerants. At the point of environmental, toxicity, stability, flammability, and thermo economical properties and conditions these proposed refrigerants must be ensured.

2.1 Global warming potential (GWP)

Global warming means the increase in the average temperature of earth. The reasons of global warming are increasing CO2concentration, NO2emission and the use CFC refrigerants. The ability of a substance to contribute global warming is measured by global warming potential. Fig1 shows the stages of three refrigerants and Global concern about depletion of the ozone layer resulted in the **Montreal Protocol** [9], it was an international treaty that established phase-out dates for the use and production of ozone-depleting substances. It went into effect in 1987, first targeting CFCs, then HCFCs. CFCs were replaced with HCFCs, which have lower ozone-depletion potential (ODP), or with hydro fluorocarbons (HFCs), which have zero ODP. The CFC phase out was completed in 1996. Due to their low ODP, the phase-out dates for HCFCs were set out later from 2004 to 2030 (2040 in developing countries).

2.2 Ozone depletion potential (ODP)

The relative ability of a substance to deplete the ozone layer called ozone depletion potential. It may be mentioned that one chlorine atom can destroy 105 ozone molecules. In the 1990s, concerns grew that the refrigerants being phased in because of their favorable ODP were contributing to global warming. The global-warming potential (GWP) of refrigerants now became a factor. These concerns with global climate change led to the **Kyoto Protocol** [10], created in 1997. Kyoto sets reduction targets for greenhouse gases, including HFCs, in developed countries. Because CFCs and HCFCs were already insured under the Montreal Protocol, they were not included in the Kyoto Protocol. Fig2 represents the ODP for the three refrigerants.

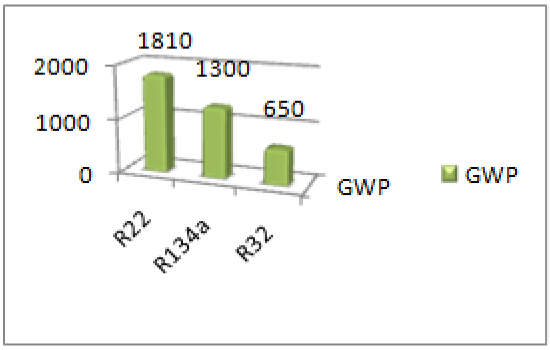

Fig1: GWP levels for selected refrigerants

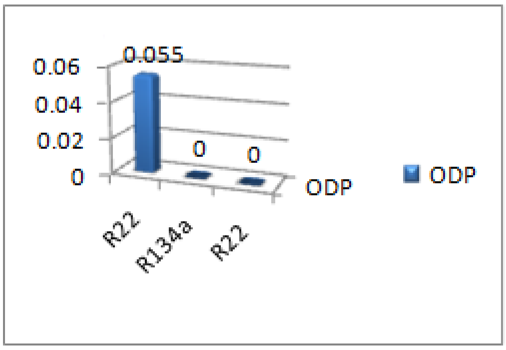

Fig2: ODP levels for selected refrigerants

Table1: Some properties of selected alternative refrigerants

Sl. No.	Properties	R22	R134a	R32
1.	Gas type	HCFC	HFC	HFC
2.	Molecular formulae	$CHClF_2$	CH_2F_4	CH_2F_2
3.	Chemical name	Chlorodifluoromethane	Tetrafluoroethane	Difluoromethane
4.	Boiling point @ 1atm	-41^0C	-26.1^0C	-52^0C
5.	Safety designation (ASHRAE 2001)	A1-non-toxic and non-flammable	A1- non-toxic and non-flammable	A2L-non-toxic and mildly-flammable
6.	Critical pressure	49.9 bar	40.6 bar	53.8bar
7.	Critical temperature	96.15^0C	100.95^0C	78.4^0C
8.	Ozone depletion potential (ODP)	0.055	0	0
9.	Global warming potential (GWP)	1810	1300	650

III. Working principle

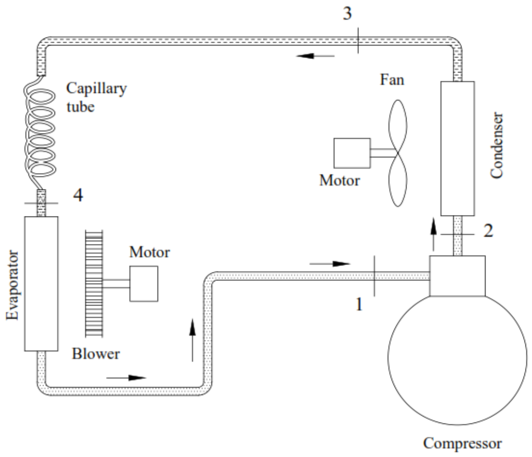

Fig3: Simple vapor compression refrigeration cycle

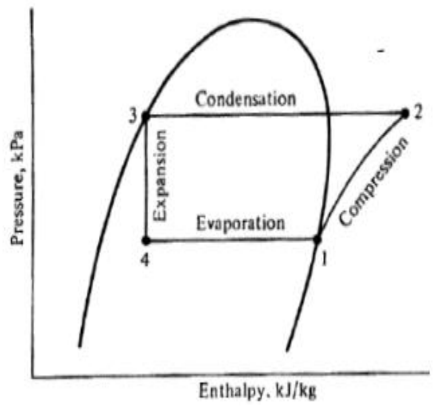

Fig4: P-H diagram of VCR cycle

As shown in the fig3 the basic system consists of an evaporator, compressor, condenser and an expansion valve. The refrigeration effect is obtained in the cold region as heat is extracted by the vaporization of refrigerant in the evaporator. The refrigerant vapor from the evaporator is compressed in the compressor to a high pressure at which its saturation temperature is greater than the ambient [11]. Hence, when the high pressure, high temperature refrigerant flows through the condenser, condensation of the vapor into liquid takes place by heat rejection to the heat sink. To complete the cycle, the high pressure liquid is made to flow through an expansion valve. In the expansion valve the pressure and temperature of the refrigerant decrease. This low pressure and low temperature refrigerant vapor evaporate in the evaporator taking heat from the cold region. It should be observed that the system operates on a closed cycle. The system requires input in the form of mechanical work. It extracts heat from a cold space and rejects heat to a high temperature heat sink. Fig4 represents the p-h diagram for VCR cycle and from p-h diagram the processes are as follows.

Process 1-2: Isentropic compression of saturated vapor in compressor
Process 2-3: Isobaric heat rejection in condenser
Process 3-4: Isenthalpic expansion of saturated liquid in expansion device
Process 4-1: Isobaric heat extraction in the evaporator

3.1Retrofitting process

The system consists of following components, they are hermetically sealed compressor, condenser, expansion device (capillary tube), pressure gauges, gas charging valves, Rota meter, thermocouples, evaporator, and refrigerants (R22, R134a, R32).

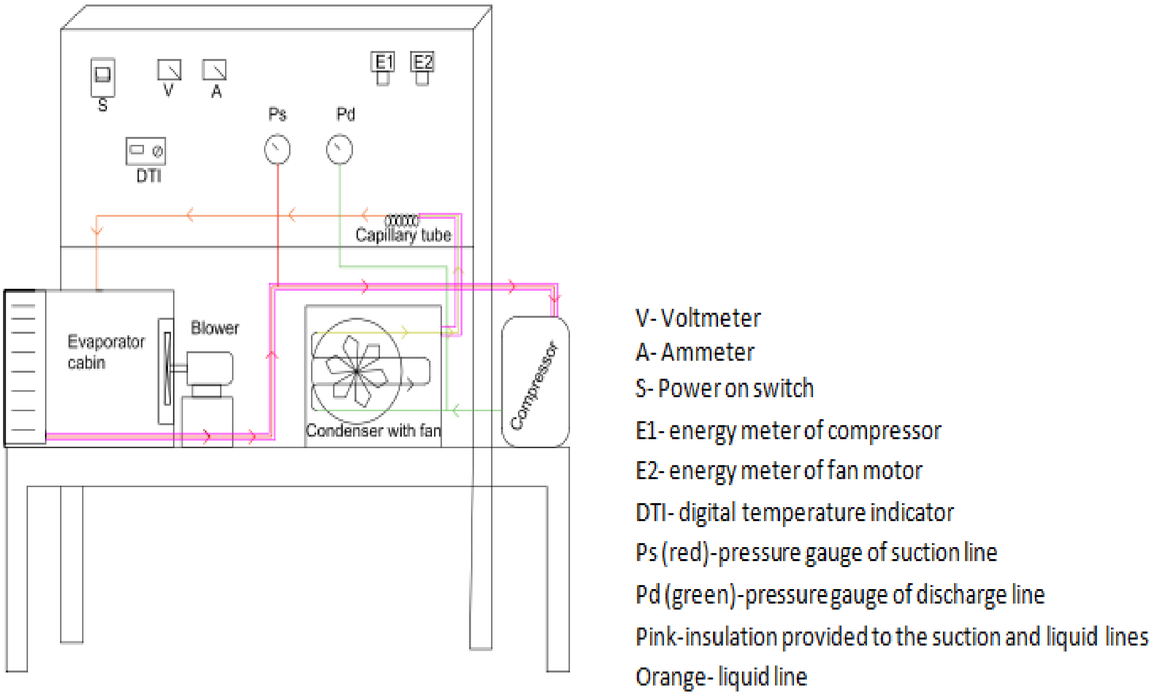

Fig5: Schematic diagram of air conditioner test rig

The above schematic diagram represents an experimental setup for air conditioning system. Here the retrofitting process was carried as follows: Initially leakage tested with N_2gas and the system is charged with R22 gas through charging valves. Note down the initially energy meter readings of compressor and condenser fan motor. Switch on the power button to start the experiment and note all the readings as given in observations after every 15 minutes.

T1 – temperature of refrigerant at compressor inlet
T2 – temperature of refrigerant at compressor outlet
T3 – temperature of refrigerant at condenser outlet
T4 – temperature of refrigerant at evaporator inlet
T5 – temperature of refrigerant at evaporator outlet (room cooling temp)

3.2 Performance parameter analysis

Whenever the minimum temperature is attained in the conditioned room at the steady state level the actual coefficient of performance (C.O.P) of the system is calculated so, it is the ratio of refrigeration capacity to the actual work input to the compressor.

Experimental C.O.P = h1-hf3 / h2-h1

The mass flow rate of the refrigerant (mr) is defined as the ratio of the refrigeration capacity to the refrigeration effect that was produced in the system.

m_r= refrigeration capacity/refrigeration effect

The compressor pressure ratio is defined as it is the ration of compressor discharge pressure (P_d) to the compressor suction pressure (P_s)

$P_R = P_d / P_s$

IV. Simulation Analysis

4.1 About aspen

The purpose of analysis/simulation is to model and predict the performance of a process. ASPEN plus is a computer-aided software which uses the underlying physical relationships (e.g., material and energy balances, thermodynamic equilibrium, rate equations) to predict process performance (e.g., stream properties, operating conditions, and equipment sizes). It is a market-leading process modeling tool for different area of applications like conceptual design, optimization, metals and minerals, coal power industries and performance monitoring for the specialty chemical.

Aspen Plus is one of the core elements of AspenTech's aspen ONE Engineering applications. Here aspen plus V8.0 is used for process simulation [12]. The Simulation environment contains the main flow sheet area where the majority of the work (installing and defining streams, unit operations, columns and sub flow sheets) is done. The flow sheet area in Aspen software points the various components needed to draw a flow sheet and henceforward, the flow sheet is simulated.

4.2 Process simulation

Process analysis may involve the use of experimental means to predict and validate performance. Then in the simulation process, we need to give the initial process inputs, flow sheet and are required to predict process outputs.

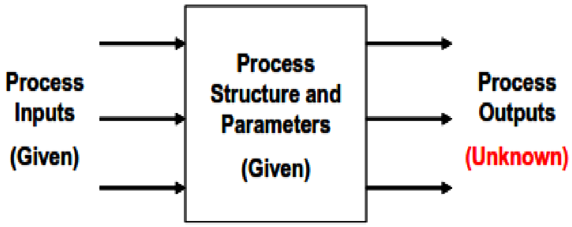

Fig6: process simulation

4.3 Results and Discussions

The following table2 represents theoretical calculation results for the three alternative refrigerants of performance parameters. Those values are validated with the aspen one process simulation results.

Figure7 shows that flow diagram of VCR cycle, in this process each individual component is simulated and then connected as a closed loop. A similar process is done for the remaining refrigerants. Figure8 shows that what are the different phases of refrigerant that are present in the VCR cycle after the simulation process. Here red color indicates vapor phase, blue indicates liquid phase, and green indicates mixed (both vapor and liquid) phase. table3 indicates that validation results that are considered from the experimental and process simulation.

Table2: Experimental calculation results for three refrigerants

Refrigerant	Mass flow rate	Pressure ratio	Max C.O.P	Experimental C.O.P	Optimum cooling temp.
R22	0.037	3.67	3.36	3.07	13
R134a	0.033	3.34	3.77	3.22	10
R32	0.021	3.54	3.90	3.47	8

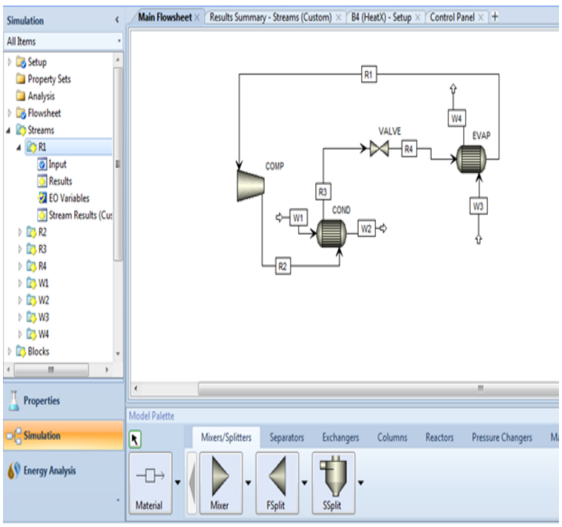

Fig7: Flow sheet of VCR cycle

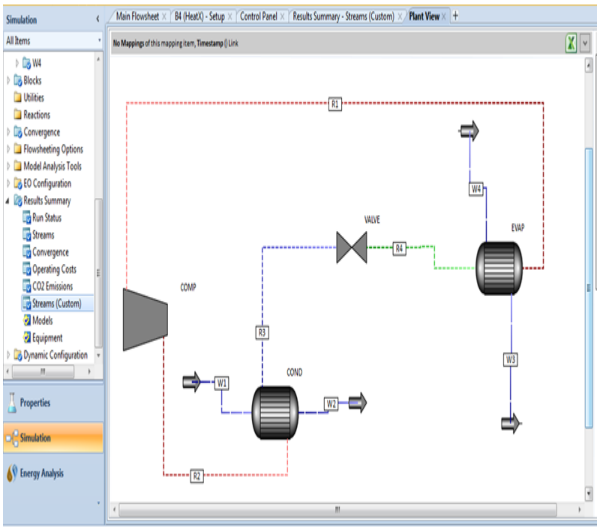

Fig8: Process simulation of VCR cycle

Table3: Validation of Results

Refrigerant	Experimental C.O.P	Process simulation C.O.P	% of error
R22	3.07	3.11	1.28
R134a	3.22	3.26	1.22
R32	3.47	3.51	1.13

V. Conclusions

Depending on the experimental and process simulations the following conclusions were made.

- With the same ambient conditions of three refrigerants the R32 gives optimum cooling temperature.
- R32 gives a high coefficient of performance, then compare to the other two refrigerants, even though a small increase in power consumption.
- Not only that in process simulation also the difluoromethane gives a better coefficient of performance, hence it was the good retrofit refrigerant for the air conditioner test rig.

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