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Performance Assessment of Window A/C under Drop- In Condition Using Propane as Refrigerant

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ABSTRACT : *R22 is a HCFC refrigerant and it is to be eliminated by 2020, because of its ozone-depletion-potential. This generates a need for the investigation of zero ozone-depletion-potential (ODP) refrigerants with properties similar to CFCs and HCFCs to be used as replacements. R-290 is a refrigerant with zero ozone-depletion-potential. Therefore the compatibility of the existing air conditioner unit for R290 should be checked which is presently working on R22 refrigerant and performance is also evaluated and compared. The comparison should be done on the basis of ozone depletion potential, cooling capacity, thermal exchange properties, and system efficiency, mass flow rate, power consumption of system etc. As a general conclusion, it is observed that using R290 as refrigerant will result COP equal to, or higher than, those of HCFC systems currently in use. It is also shown that components of R22 system are suitable for R290 systems which are easily available in market. Safety issue is a major concern that should not be taken lightly. Reduced charge through indirect systems and compact heat exchangers, outdoor placing of the unit, hydrocarbon sensors and alarms and forced ventilation are all the major steps which may be applied to reduce the risks under normal operation.*

Keywords - Window A/C, Refrigerant, Propane R-290, R22, COP.

I. INTRODUCTION

Many researches have taken place to replace the existing traditional refrigerants by refrigerant having similar characteristics with less Ozone depletion potential and Global warming potential. I. L. Maclaine-cross, E. Leonardi. (June 1997) had performed experimental comparisons of refrigerants Energy consumption of domestic refrigerators and found that for R290 the cooling capacity was about 20% higher and the energy consumption about 5% higher than for R12 [1]M. A. Hammad, M. A. Alsaad (1999) had done an experimental study for evaluating the performance parameters of a domestic refrigerator when four ratios of propane, butane and isobutane are used as possible alternative replacements to the traditional R-12 refrigerant. [2] Eric Granryd (2001) worked to identify the Possibilities and problems of using hydrocarbons as working fuids in refrigerating equipment. The general conclusion is that hydrocarbons offer interesting refrigerant alternatives for energy efficient and environmentally friendly refrigerating equipment and heat pumps. However, safety precautions due to flammability must. [3] Dongsoo Jung (2004) measured an External condensation heat transfer coefficients of six flammable refrigerants of propylene (R1270), propane (R290), isobutane (R600a), butane (R600), dimethylether (RE170), and HFC32 and concluded that external condensation heat transfer coefficients decrease with the wall sub cooling. No unusual behaviour or phenomenon was observed for these fluids during experiments. HFC32 and RE170 showed 28–44% higher heat transfer coefficients than those of HCFC22 due to their excellent thermo physical properties. [4] Mao-Yu Wen (2005) was studied flow boiling heat transfer for pure R-290, R-600, and R-134a and mixed refrigerant R-290/R-600 (55 wt. %/45 wt. %) in the three-line serpentine small-tube bank. The influences of mass velocity and heat flux to the evaporation heat transfer and pressure drop characteristic were examined and discussed and found that if R-290, R-600 or R-290/R-600 are used in a new refrigeration system, the exchanger size is expected to be small and the system performance will be better. [5] Akio Miyara (2008) studies on condensation of hydrocarbons are reviewed and conclude that since the hydrocarbons have similar and superior thermo physical properties to conventional fluorocarbon refrigerants, there are no significant differences in physical phenomena and the heat transfer performance of the heat exchanger and the COP of the system with hydrocarbons become higher than those with fluorocarbons. [6] Bjom Palm (2008) has investigated the properties of the hydrocarbons propane, propene and isobutane and compared them to R22, R134a and ammonia. It is shown that the properties of the hydrocarbons make them suitable as refrigerants and that the system efficiencies should be expected to be equal to, or higher than, those of R22 and R134a systems. [7] The risks caused by the flammability of the hydrocarbons must be taken seriously. The risks can be reduced by designing the systems for minimum charge of refrigerant, careful leak detection during production, hermetic design with minimum number of connections, use of spark-proof electric components and ventilation of confined spaces.

In conclusion, it seems likely that the hydrocarbons will continue to be used as refrigerants in small- and medium-sized refrigeration, AC and heat pump system. However, working with these fluids requires careful design and skilled personnel for manufacturing and servicing.

Now a days refrigeration and air conditioning becomes an essential part of human being. It is widely used in commercial as well as in residential areas for the purpose of food preservation and conditioning of air for comfort. It is found that refrigerants used causes Ozone depletion if they get leaked. With ozone layer depletion, more harmful ultraviolet rays reach the Earth's surface and may cause skin cancer and other problems like global warming.

CFCs were phased out by January 1996, except for essential users, and HCFCs are to be eliminated by 2020 as per the amended version of the protocol. Because of which it is becoming essential to investigate a refrigerant or refrigerant blends with properties similar to CFCs and HCFCs and with zero ozone-depletion-potential (ODP) to be used as replacements in existing systems and also for the design of newer air-conditioning and refrigeration systems. R22 is the most commonly used refrigerant in air-conditioning industry. Two different approaches were taken while reviewing the alternatives to R22. The first was to develop a substitute refrigerant with similar characteristics to R22 which can be used in system without redesign of existing equipments. The second approach was to develop a substitute refrigerant, which would give the best performance when applied to the redesigned equipment, which traditionally uses R22. R290 is the substitute with better thermodynamic performance.

Refrigerants should satisfy thermodynamic requirements to efficiently deliver sufficient capacities. Refrigerants should be locally safe in equipment and globally safe for the environment. R-290 could be considered as potential working fluid for air conditioning system due to their zero ozone-depletion-potential and low global warming potential characteristics.

This study will help to provide a clear understanding of the relative performance potential of R-290 as compared to existing HCFCs R-22 refrigerant used in air conditioning systems. An experimental evaluation of the R-22 and R-290 refrigerants was investigated.

II. OBJECTIVE OF WORK

The R22 is a HCFC refrigerant and it has to be eliminated by 2020, because of its ozone-depletion-potential. This generates a need for the investigation of zero ozone-depletion-potential (ODP) refrigerants with properties similar to CFCs and HCFCs to be used as replacements. R-290 is a refrigerant with zero ozone-depletion-potential. Therefore the compatibility of the existing air conditioner unit for R290 should be checked which is presently working on R22 refrigerant.

III. METHODOLOGY OF PROJECT

The project work is to find out the compatibility of the existing air conditioner unit for R290 which is presently working on R22 refrigerant. The compatibility should be evaluated on thebasis of various parameters obtained in the experimentation.A window air conditioner unit should be tested with R22 as a refrigerant under full load condition to find out the following parameters:

1. Temperatures at: compressor inlet, compressor outlet, condenser outlet, capillary outlet, evaporator outlet.
2. Pressures at: compressor suction, compressor discharge.
3. Temperature and humidity of supply and discharge air.
4. Flow rate of the air supplied from the air conditioner.

By using the above parameters the performance (COP) of the air conditioner unit is calculated for full load condition.A known mass flow rate R290 is filled in the same air conditioner unit and the test was conducted in the same way to find out performance (COP) of the unit. Filling of more R290 refrigerant in the air conditioner unit and test is carried out till A/C unit gives same suction and discharge pressure of compressor and same COP as it gave in previous test with R22 refrigerant. On the basis of same performance of the air conditioner unit with R22 and R290 refrigerant other parameters like power consumption, mass flow rate and refrigeration effect was compared.

IV. EXPERIMENTATION

Experimental setup:

The schematic diagram of the experimental setup is shown in Fig. 1 it consists of the following components:

- A window air-conditioner unit: 1.5TR capacity.
- Pressure gauges to measure suction and discharge pressure of compressor.
- Temperature sensors and indicator to measure temperature at various points.
- Wattmeter to measure power input to AC.
- A duct to make the flow of air confined for measuring the flow rate.
- Pitottube and temperature probe for measuring flow rate and temperature of air.

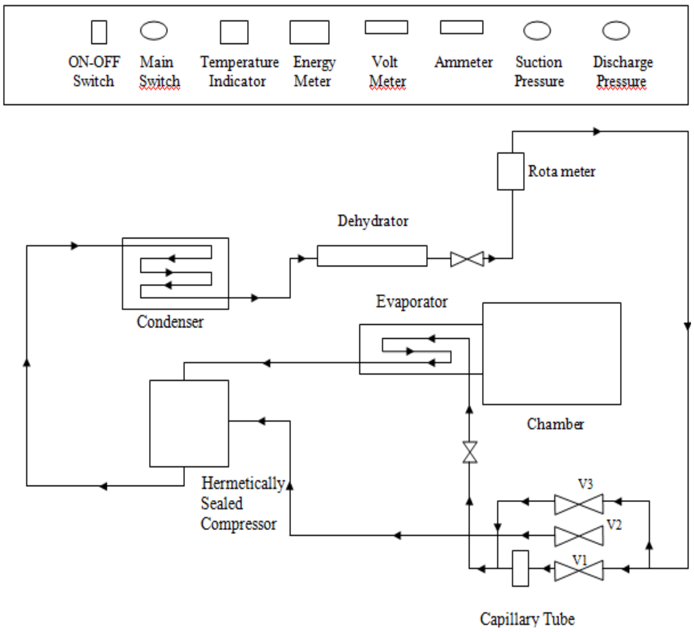

Fig.1. Experimental set-up

Instrumentation

Wattmeter: Wattmeter is used to measure the actual power input or electrical energy supplied to the compressor in kW.

Energy Meter: To measure power input Energy meter was also used along with Wattmeter. Time required for 20 revolutions of energy meter disk was measured in seconds and calculations are done by using mathematical formula.

Pitot tube: Pitot tube is used to measure the flow rate of conditioned air supplied to room i.e. at outlet of evaporator.

Temperature sensor: To measure the temperature of atmospheric or conditioned air in room, temperature sensor probe was used.

Thermocouples: To measure the temperature of refrigerant at different locations, thermocouples are used. Temperatures of refrigerant at inlet to compressor; Outlet of compressor; Outlet of condenser; Inlet to evaporator were measure.

Temperature indicator: All thermocouples were attached to temperature indicator which acts as a display.

Pressure Gauges: Pressure gauges were used to measure pressure of refrigerant corresponding to temperatures measured with thermocouples for different locations stated above.

Propane storage cylinder: To store the refrigerant during experimentation storage cylinder was required. The mass of refrigerant in the system was calculated by taking difference between initial and final weight of the cylinder.

Connector: While charging the inlet line of this compressor was connected to the propane storage cylinder through connector.

Compressor: Compressor other than system compressor was used to remove refrigerant present in the system. Then refrigerant from cylinder was allowed to pass in to system and charging was done.

Test Condition: The test conditions were decided on the basis of actual measurement with the help of instruments discussed above. The test was carried out under following conditions

Outside Conditions: Atmospheric temperature rang 27 – 30 °C; Humidity in the room 30 – 40 %;

Inside Conditions: Evaporator Pressure 3 – 6 bar; Condenser Pressure 17 – 20 bar; Evaporator Temperature 5 – 10°C; Condenser Inlet Temperature 66 – 78°C; Mass of refrigerant 280 – 400 gm for R290 and 720 gm for R22.

V. RESULTS AND DISCUSSION

The results for the test are presented in Table 1 and graphical form. It is observed that the cooling capacity and COP varies with the amount of refrigerant. To begin with observations are taken by using R22 as refrigerant and COP of the system is calculated then the R22 is replaced by R290 and same observations are taken to calculate COP corresponding to quantity of R290 filled in the system. The quantity of refrigerant R290 for which the COP of the system is same as in previous case that is with R22 as refrigerant, is considered as the optimum weight of R290 refrigerant for the system. Then the comparison between performance of R290 and R22 is made when the COP of both the systems are same and is evident from Fig. 2. It is observed that for same COP, the specific refrigerating effect of R290 is about 40% greater than R22 as R290 has high latent heat of vaporization. But actual cooling capacity of system with R290 is observed 8.86% less as compared to the system with R22. This is due to lower mass flow rate of R290 refrigerant in the system. Calculations show that for this actual refrigerating effect 43% less R290 refrigerant is required as compared to R22 refrigerant. On the basis of available calculations it is concluded that the system achieve same cooling capacity using 38% less R290 refrigerant as compared to R22 refrigerant. Also it is observed that for same COP the power consumption of system with R290 as refrigerant is about 11.16% less than the system with R22 as refrigerant.

Table 1.Results of the Experiment

Refrigerant	Weight of refrigerant (g)	Cooling Capacity(kw)	Compressor power(kw)	Actual COP
R290	280	3.94	2.18	1.81
	280	4.06	2.20	1.85
	300	4.20	2.40	1.75
	360	4.83	2.23	2.16
	400	4.03	2.34	1.72
R22	720	5.30	2.51	2.11

DISCUSSION:

The results as shown in Table 1 shows that even though the latent heat of vaporization of R290 is more than R22, the actual refrigerating effect of the A/C unit is less when the R22 is replaced by R290 to achieve same COP. This is because of less mass flow rate of R290 in the system as compared to R22. The thermodynamic cycle is plotted on the p-h chart as shown in Fig. 3. Table 2 shows the calculated values of Evaporator area, Condenser area, Capillary tube length and Compressor Inlet and Outlet Pressures for system using R290 and R22 as refrigerant which are approximately equal. The values above shows no need of redesigning of any component of the system. The pressures at inlet and outlet of the compressor observed during the test for both the refrigerant are also same, which shows no need of compressor replacement or redesigning of it. Hence existing system of R22 can be used for the purpose of performance testing of R290 just by replacing R22 with R290 refrigerant.

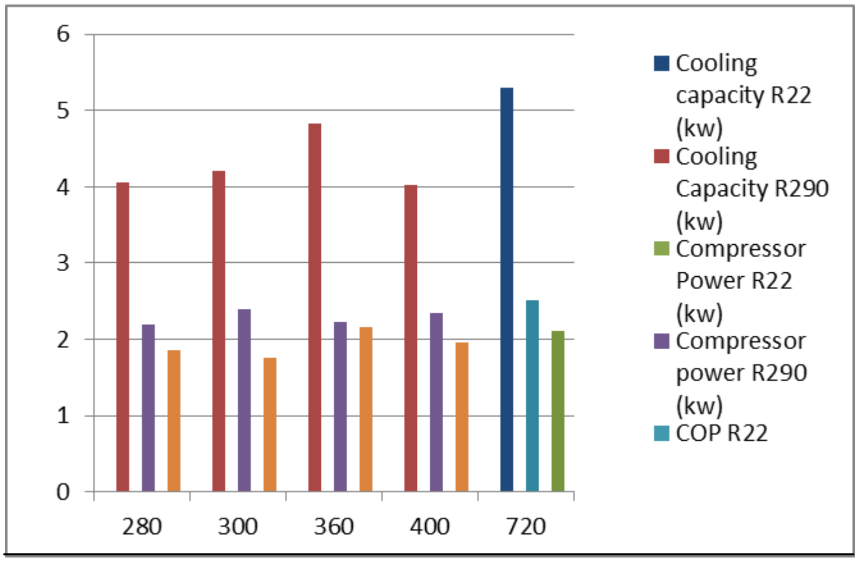

Fig. 2 Comparison of R290 and R22 performance

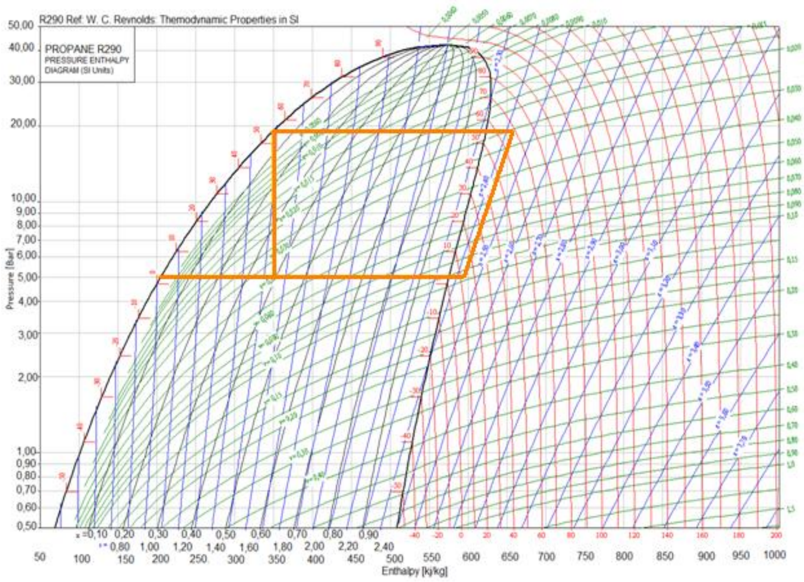

Fig. 3 p-h Diagram for the Refrigerant R290

Table2. Comparison of Results for Heat Exchanger Area, Capillary Length & Compressor inlet-outlet Pressure

Evaporator Area (m^2)		Condenser Area(m^2)		Capillary Length (m)		Compressor Inlet Outlet Pressure (Bar)			
R290	R22	R290	R22	R290	R22	R290		R22	
						Inlet	Outlet	Inlet	Outlet
0.16	0.12	0.4	0.49	1.15	1.22	73	280	72	280

VI. SAFETY CONSIDERATIONS

When considering a mixture of a flammable fluid and air, burning or explosion can occur upon contact with a source of ignition in the case that the mixture concentration is between the lower explosive limit (LEL) and the upper explosive limit (UEL). Propane sensors would have been installed nearby the compressor and inside electrical panels. These sensors detect from 0 - 20% of the LEL and different safety levels have been considered depending on the concentration measured by the sensors. When a level from 0 - 20% of the LEL is detected (i.e. safety level 1), the system switches off keeping the microprocessor operating and a signal of alarm is produced. Furthermore, the two fans provided are switched on in order to disperse the concentration to the environment external to the equipment case. When a propane concentration above 20% of LEL is detected i.e. safety level 2 or sensor fault is detected by auto-diagnosis i.e. safety level 3, the microprocessor is also switched off, while the fans are kept operating as well as the sensors and the electric panel small fans fed by the buffer battery. The system should be situated outside in open air on the roof of the building and keeping the system casing partly open; this provides a reasonable level of intrinsic safety.

VII. CONCLUSION

R290 has zero ozone depletion potential. It has a higher cooling capacity and has better thermal exchange properties compared to R22, this results in overall performance gain in terms of system efficiency. For same COP of the systems the specific refrigerating effect of R290 is about 40% greater than R22. Actual refrigerating effect of system with R290 is about 8.86% less as compared to the system with R22. This is due to the lower mass flow rate of R290 refrigerant in the system. On the basis of calculations it is concluded that to achieve same cooling capacity 38% less R290 refrigerant is required as compared to R22 refrigerant. If comparison is done on the basis of same COP then it is observed that power consumption of system with R290 as refrigerant is about 11.16% less than the system with R22 as refrigerant. R290 operates at same evaporator and condenser pressure as R22, therefore compressor used for R22 system can be used in R290 system and should not be redesigned or replaced. Also there is no need of redesigning or replacing of any component used in R22 system for performance testing of R290 refrigerant. Air conditioning unit of small capacity for performance testing of R290 can be developed by using hermetically sealed reciprocating compressor, Evaporator, Condenser and Capillary tube with same specification as used in system with R22 as refrigerant.

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