

# Experimental performance study of R290 as an alternative to R22 refrigerant in a window air conditioner

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**Abstract.** R22 is a hydrochlorofluorocarbon (HCFC) refrigerant widely used in air conditioning. R22 is an ozone depleting substance. Due to ozone layer depletion, HCFC will be phased out in near future. R290 is hydrocarbon (HC) refrigerant is an alternative to R22. This paper presents outcomes of this comparative study. A 1 ton capacity window air conditioner was used to experiment. R22 was used for baseline refrigerant. R290 refrigerant using air cooled condenser coefficient of performance (C.O.P.) lowered by 6.91%, 6.28% & 1.38% at different set point temperatures 16°C, 20°C & 25°C. The system is optimized to increase in thermodynamic performance by using evaporative cooling condenser with R290 refrigerant. C.O.P. of system is improved by 15.84%, 18.23% & 22.92% at different set point temperature and power consumption reduces by almost 50% than the baseline system. The amount of refrigerant charge of R290 refrigerant is 70% less than that of R22 refrigerant. Experimental results show that implementation of the evaporative cooled air condenser by using R290 refrigerant has a significant effect on performance improvement of window air conditioner.

## 1. Introduction

R22 is widely used refrigerant in air conditioning all over the world. The growing global demand for room air conditioner increases the usage of R22. Due to its environmental concern of ozone depletion, it is a controlled substance under the Montreal Protocol. As per accelerated phase out schedule, the R22 has to be phased out before 2030 in developing countries and 2020 by developed countries [1, 2]. The accelerated phase out schedule poses a major challenge for developing countries. At present, HFC (hydrofluorocarbon) alternatives to R22 for ACs are R407C & R410 A. However, with a relatively high GWP (global warming potential) of HFC & uncertainties of the future of such HFCs, they are not preferred as long term alternatives. Some developing countries, including India and China, are searching for a long term alternative instead of opting for an intermediate solution of HFCs. Therefore, there is a lot of interest in natural fluids like hydrocarbon. Propane (R290) is considered as an energy efficient replacement due to its similarity to R22 except for its flammability.

Many studies have revealed the advantage of R290 in air conditioner and heat pump. Park and Jung (2008) [3] showed that R290 when used in air conditioner, the refrigeration capacity was lowered by 8.2% and coefficient of performance was 11.5% higher than that of R22 system. Zhou et.al. (2010) [4] has found in air conditioner R290 had 4.7-6.7% lower cooling capacity & 8.5% higher EER (energy efficiency ratio) as compared to R22 systems. Tun-Ping Teng et.al. (2012) [5] found experimentally best charged mass for air conditioner of refrigerant R290 was 50-55% than that of R22 by weight. EER of R290 increases by 20% of than that of R22 system. J.H. Wu et.al. (2012) [6] found 550g R290 optimum charge, EER is 0.8% higher than R22 under normal condition. The optimum charge to



obtain by performance is far beyond the regulated by EN378. It has been found by many researches that R290 performance was equal to or better than the existing system with HCFCs or HFCs.

This paper presents the experimental performance of 1 ton capacity Window air conditioner with R22 as baseline refrigerant and R290 as an alternative refrigerant. R290 refrigerant to the original system with air cooled condenser and optimized system with evaporative cooling condenser for better performance of the air conditioner.

## 2. Experimental programme

### 2.1. Experimental setup

An original R22 Kenstar Window air conditioner model KT12HT ,whose charge is 1000g ,capacity 1ton is adopted as baseline system and retrofitted to charge R290. Experimental setup together with a measuring instrument can be seen in figure 1.



**Figure 1.**Experimental setup.

The measuring instruments were used in recording the test results during the experiment as listed in table 1.

**Table 1.** Specifications of the measuring instrument used in the experiment.

Measuring instrument	Measurement range	Accuracy
Pressure gauges	0 to 40 bar	$\pm 3\%$
Subzero SZ7504 Temperature scanner	-55 to 99°C	$\pm 1^\circ\text{C}$
Digital anemometer	0 to 30 m/s	$\pm 2\%$
Energy meter	5.30A ,240V	$\pm 2\%$
Weighing scale	0 to 5 kg	$\pm 1\text{g}$

## 2.2. Safety of R290

R290 is flammable as per ASHRAE standard 34, R290 is classified as class 3 (highly flammability fluid). The lower flammable limit (LFL) and upper flammable limit (UFL) of R290 are 2.1% and 9.5% respectively by volume of air. The safety precaution to be taken based on the refrigerant charge quantity and physical location of the unit. Charge size limitations are set considering the flammable concentration should below the LFL, if the whole charge leaks and diffuses into the given space. According to European standard EN378 [7] maximum allowable charge in the room can be calculated using equation (1).

$$m_{\max} = 2.5 \times \text{LFL}^{5/4} \times h_0 \times A^{1/2} \quad (1)$$

Where

$m_{\max}$  is the allowable maximum charge in a room in kg;

$A$  is the room area in  $m^2$ ;

LFL is the Lower Flammable Limit (LFL) in  $kg/m^3$ ;

$h_0$  is the installation height of the appliance in m;

— 0.6, m for floor location;

— 1.8 m for wall mounted;

— 1.0 m for window mounted;

— 2.2 m for ceiling mounted.

From the experimental room specification  $A = (10 \times 8) m^2$ , LFL =  $0.038 kg/m^3$  for R290  $m_{\max} = 0.375 kg$  and for the 1 ton window air conditioner of the experiment the optimum amount of the charge was found to be 300g by varying the charge 200g, 250g and 300g for all tests conducted using R290 refrigerant.

## 2.3. Experimental procedure

In this study, a 1 ton capacity window air conditioner unit designed for R22 was selected for performance evaluation with R290. The performance was measured for both R22 and R290 refrigerant. Further during optimization study, the air cooled condenser is converted into the evaporative cooled air condenser. Evaporative cooling air condenser system made by spraying water on the top of the right and left side media pad. It includes a small pump, tank and a water injection pipe as shown in figure 2. It is used to improve performance of the system with R290 refrigerant. Increase in condenser temperature decreases cooling capacity, C.O.P of the cycle due to reduction of liquid content in the evaporator. To reduce the condenser temperature, application of evaporative cooler is one of the easiest ways. By which the condenser temperature decreases, thus the cooling capacity and performance of the unit become better.

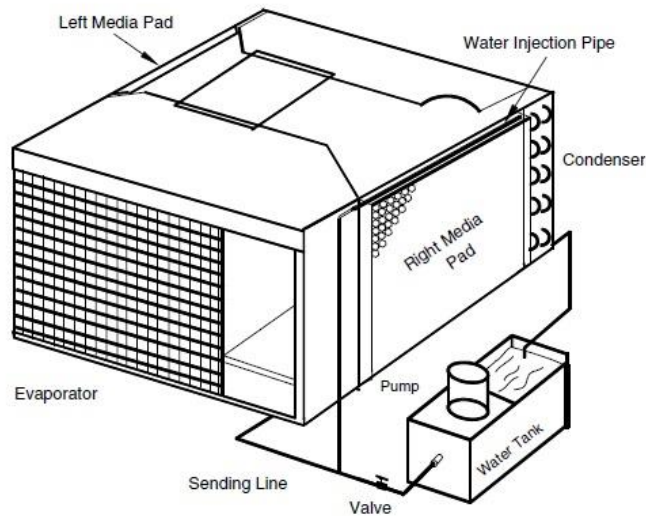
All tests were conducted at various set point temperatures  $16^\circ C$ ,  $20^\circ C$  and  $25^\circ C$ . The following different cases were considered;

Case 1: R22 for baseline performance.

Case 2: R290 with air cooled condenser.

Case 3: R290 with evaporative cooling condenser.

For all the tests the ambient air temperature was maintained at  $35^\circ C$ . The performance parameter C.O.P., Power consumption, Refrigeration effect, pressure ratio was compared. All safety standards for using R290 were duly considered and implemented for the experiment.



**Figure 2.** Schematic diagram of Evaporative cooling air condenser.

#### 2.4. Performance parameter calculations

Vapour compression in the refrigeration cycle, refrigerant temperature, operating pressure, temperature, power consumption, COP was analyzed. The thermodynamic properties of the R22 and R290 refrigerants were calculated using COOLPACK software. The Pressure ratio, Refrigeration effect and C.O.P. were calculated as follows [8, 9, 10]:

1) Pressure ratio is calculated using

$$\text{Pressure ratio} = \frac{P_{\text{condenser}}}{P_{\text{evaporator}}} \quad (2)$$

2) Refrigeration effect is calculated using

$$\text{Refrigeration effect } (Q_e) = \Delta h_{\text{evaporator}} = (h_1 - h_4) \text{ KJ/kg} \quad (3)$$

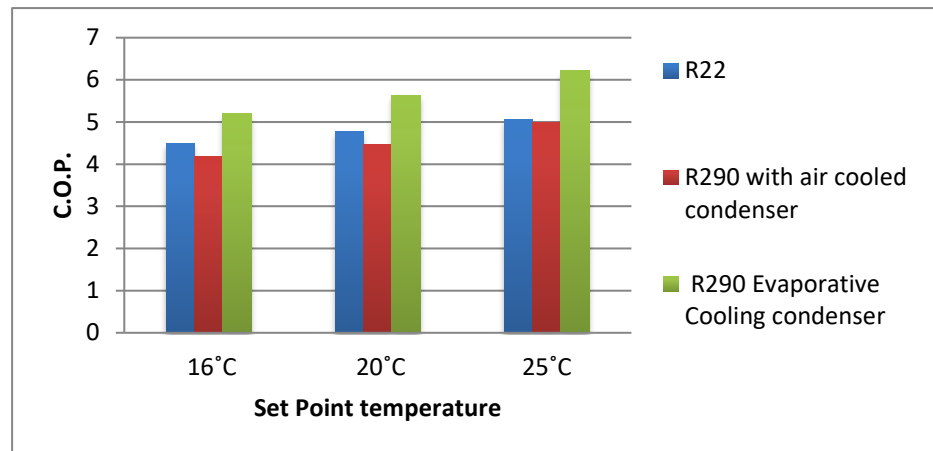
3) C.O.P. is calculated using

$$\text{C.O.P.} = \frac{\Delta h_{\text{evaporator}}}{\Delta h_{\text{compressor}}} = \frac{(h_1 - h_4)}{(h_2 - h_1)} \text{ KJ/kg} \quad (4)$$

### 3. Results and discussion

#### 3.1. Coefficient of performance

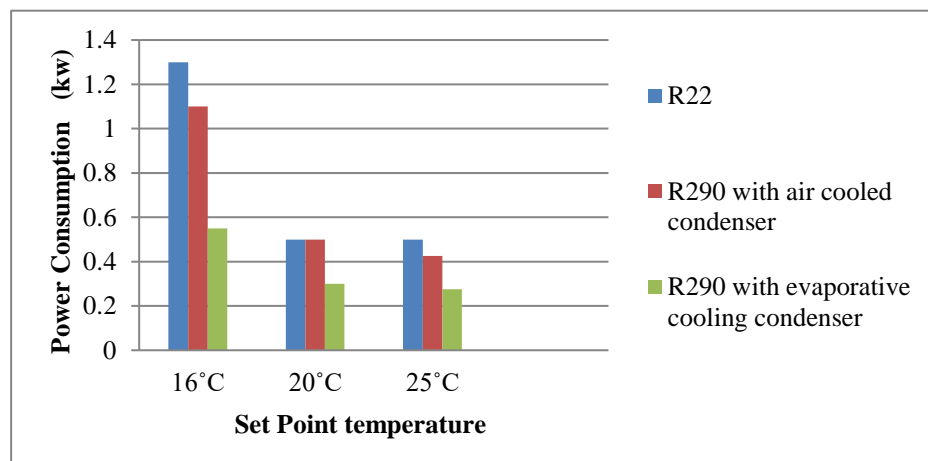
Figure 3 shows the variation coefficient of performance under different set point temperature. In terms of the C.O.P. R290 is better than R22. When air cooled condenser was used the C.O.P. of R290 is less than that of R22 refrigerant. But when evaporative condenser was used in the experiment C.O.P. of air conditioner increases significantly by 15.84%, 18.23%, and 22.92% at 16°C, 20°C and 25°C set point temperature.



**Figure 3.** C.O.P of R22 and R290 for various test conditions

### 3.2. Power consumption

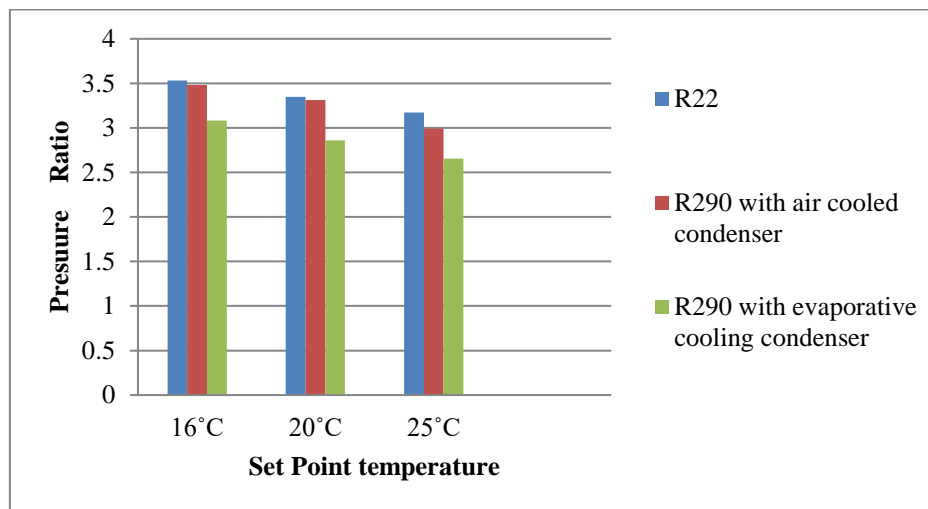
Figure 4 shows the variation in power consumption by air conditioner for different test conditions. The power consumption for the baseline system using R22 was 1.3kW, 0.5kW and 0.5kW at 16°C, 20°C and 25°C set point temperature. When R290 refrigerant with air cooled condenser was used the power consumption reduced by 15.38%, 0 % and 15% and when R290 with an evaporative cooling condenser used the reduction in power consumption is large i.e. 57.69%,40% and 45% at 16°C, 20°C and 25°C set point temperature. Therefore R290 with an evaporative cooling condenser gives best energy efficient performance.



**Figure 4.** Power consumption of R22 and R290 for various test conditions.

### 3.3. Pressure ratio

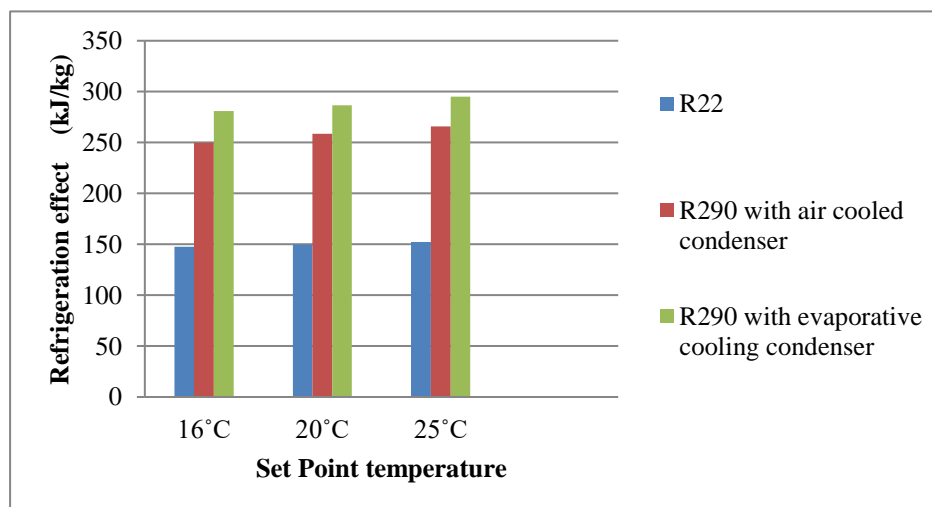
Figure 5 shows the variation in pressure ratio under different test conditions. Pressure ratio is decreased by 0.84%, 2.91 and 4% at 16°C, 20°C and 25°C set point temperature than baseline R22 system when R290 with air cooled condenser and R290 with an evaporative cooling condenser was used the pressure ratio reduction is significantly large i.e. 10.11%, 16.90% and 18.20% at 16°C, 20°C and 25°C set point temperature than the baseline system. The small pressure ratio shows high volumetric efficiency and low power consumption. [9]



**Figure 5.** Pressure ratio of R22 and R290 for various test conditions.

### 3.4. Refrigeration effect

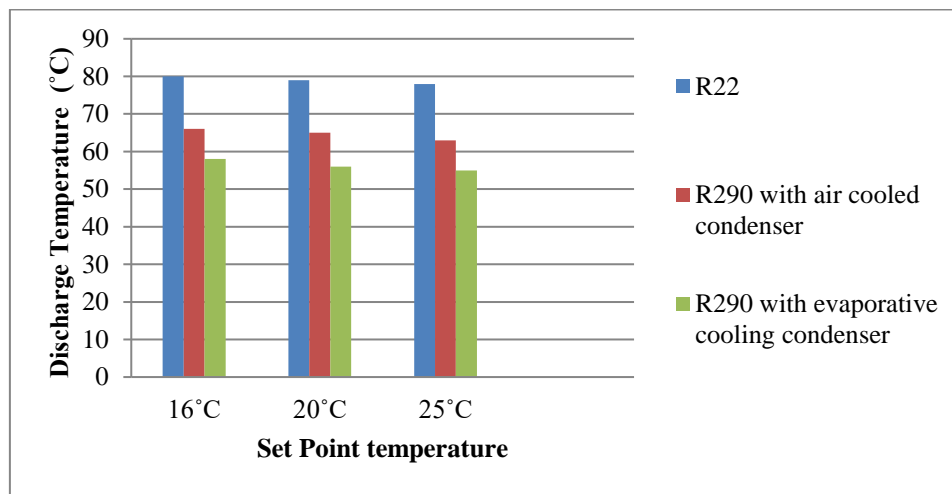
Figure 6 shows the variation in refrigeration effect under different set point condition under different set condition. R290 with an evaporative cooling condenser shows the best refrigeration effect than the baseline R22 system i.e. 89.89%, 91.28% and 93.78% increase in refrigeration effect at 16°C, 20°C and 25°C set point temperature.



**Figure 6.** Refrigeration effect of R22 and R290 for various test conditions.

### 3.5. Discharge temperature

Figure 7 shows the variation in discharge temperature of R22 and R290 under different set condition. The discharge temperature for R290 with an evaporative cooling condenser was found lower discharge temperature 58°C, 56°C and 55°C and the baseline R22 system has 80°C, 79°C and 78°C at 16°C, 20°C and 25°C set point temperature. Lower discharge temperature helps in reducing the degradation of oil and leads to increase in compressor life [9].



**Figure 7.** Discharge temperature of R22 and R290 for various test conditions.

#### 4. Conclusions

R290 is a natural refrigerant with negligible global warming potential long term alternative to R22. Based on the experimental investigation of 1 ton window air conditioner unit following conclusion could be drawn, For R290 using evaporative cooling condenser get the best performance results than the baseline system

1. C.O.P. was increased by 22.92%, 18.23% and 15.84%.
2. Power consumption was lowered by 57.69%, 40% and 45%.
3. Discharge temperature was significantly lowered by 22°C, 23°C and 23°C.
4. Refrigeration effect found to be large as compared to the baseline R22 system for various test condition.
5. The charge of R290 is 70% reduced than that of R22 by weight.

Therefore, from experimental results R290 refrigerant with an evaporative cooling condenser is best alternative to R22 refrigerant window air conditioner system.

#### Acknowledgements

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