

**COMPARATIVE STUDY ON PERFORMANCE OF ALTERNATIVE
REFRIGERANT USED IN WINDOW AIR CONDITIONER**Rajshree Kokate¹, Mahesh Teli², Naresh Teli³¹Asst. Professor of Mechanical Department, Parul Institute Engineering & Technology,²Lecturer of Mechanical Department, Parul Institute Engineering & Technology,³Lecturer of Mechanical Department, Parul Institute Engineering & Technology,

Abstract —As per the Montreal Protocol, The, phasing out of ozone depleting refrigerants has led to the quest for eco-friendly alternative refrigerants. HCFC-22(hydro chlorofluorocarbon) is used in window air conditioners. The search for alternatives to HCFC22 is a key issue in research. The objective of this work is to review on performance of various alternative refrigerants with negligible ODP and GWP values. This paper analyzed various parameters like, Cooling capacity, coefficient of performance, energy consumption, discharge pressure. HC-290 performed better than that of HCFC22. HFC407C/HC290/HC600a blend refrigerant mixture demanded lengthening of the condenser by 19% in order to maintain the discharge pressure within acceptable limits. Although Retrofitting with R-407C gave poor performance, it is an option to extend the life of air conditioning units. R1270 system with the compressor of a larger displacement has better performance with negligible loss in EER and great increase in cooling capacity when compared to R290 system. The overall performance of refrigerant mixture of 70% R123 and 30% R290 is superior to that of R12 at all evaporator conditions studied. R507 retrofitted window air conditioning system had closed performance characteristics to R22.

Keywords- Alternate refrigerant, HCFC-22, Retrofit, ozone depletion potential, global warming potential, Coefficient of performance, Cooling capacity, Energy consumption

I. INTRODUCTION

As per the Montreal Protocol, HCFC-22 can be used until 2040 in developing countries. However, many developed countries are planning to phase out HCFC-22 much earlier than the prescribed date of 2030. In Europe, HCFCs have already been phased out in new equipment (below 100 kW capacity) in 2002, and the total phase out of HCFCs is scheduled for 2015. The phase out schedule of HCFC-22 may occur much earlier than the targeted date in developing countries such as India due to market forces. It should be possible to retrofit existing systems with a more environmentally friendly refrigerant.

Due to the environmental concerns [ozone depletion potential (ODP) and global warming potential (GWP)] of the existing refrigerants, industry and researchers in this field are in search of long-term solutions. With extensive work on alternatives to chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs), initially hydrofluorocarbons (HFCs) were considered to be long-term solutions. The global warming of HFCs has become a hurdle to accept them as long-term solutions. Many refrigerants were assessed through the Alternative Refrigerant Evaluation Program (AREP) [14] as potential replacements for HCFC-22. The most promising alternative refrigerants that emerged were R-410A, R-407C, HFC-134a, and HC-290. The list has since been revised to include HFC-32, and a non-azeotropic refrigerant mixture of HFC-125, HFC-134a and HC-600 (46.6/50.0/3.4, % by mass fraction). The focus is also on the use of natural refrigerants like hydrocarbons (HCs) e.g. HC-290 and HC-600. These natural substances have the dual advantage of very low global warming, nearly zero and zero ozone depletion.

In this study, HFCs refrigerant blends are considered, whose thermodynamic behaviour is different from a pure substance, because it is a combination of pure substances which have different chemical compositions and critical points, among other properties. Therefore, there is considerable interest to assess heat exchanger performances for window air conditioners operating with alternative refrigerant under retrofit conditions.

II. ALTERNATIVE REFRIGERANT

The HVAC industry is facing two major environmental challenges today: stratospheric ozone depletion and global climate change. Stratosphere Ozone Depletion is believed to be caused by the release of certain manmade ozone depleting chemicals into the atmosphere.

HCFC22, the generally accepted and most suitable refrigerant for air conditioners must be phased out by 2030 by developed countries and 2040 by developing countries because of its Ozone Depleting Potential (ODP). Alternative refrigerants that emerged are HC-290, R404A, R507, R290, R1270, R407C, and a refrigerant mixture of HFC407C/HC290/HC600a blend, HCFC-123/HC-290 blend.

HC-290 (propane) is a common HC refrigerant. It has zero ODP, virtually zero GWP. It is a natural fluid. It has no other effect on climate, although it is considered as volatile organic compound. It is cheap and available in plenty. HC-290 is a pure hydrocarbon compound and it does not give out any toxic decomposing agents on combustion. It is

compatible with the materials and lubricants used in refrigeration and air conditioning industry. Due to better miscibility with oil, the oil return to the compressor is not an issue.

R1270 have zero ozone depletion potential (ODP) and negligible GWP, doing no harm to the environment [2]. It has favourable characteristics as refrigerants from the point of view of both thermodynamic and transport properties. In addition, R290 and R1270 have extensive sources and low cost, and are perfectly compatible with the lubricants and materials commonly being used in HVAC [3]. The only problem with R290 and R1270 is that their high flammability would induce dangerous incidents if not properly handled, just as all other flammable substances, for which the international societies always take their use seriously while once prohibiting any use [4].

Freon-12 (Dichlorodifluoromethane) is non-flammable, non-toxic and non-explosive. It is highly chemically stable. If it is brought in contact with open flame or heater elements, it decomposes into highly toxic constituents. It has not only excellent safe properties but also condenses at moderate pressure under normal atmospheric conditions.

Table 1 shows environmental data of some refrigerants.

Table 1: Environmental data of some refrigerants [5]

Refrigerants	ODP	GWP (time horizons of 100 year)
CFC-11	1	4600
CFC-12	0.82	10600
HCFC-22	0.034	1700
HCFC-123	0.012	120
HFC-134a	0	1300
HFC-152a	0	120
R-407C	0	1700
R-410A	0	2000
HC-290	0	~20
HC-600a	0	~20
Ammonia (R-717)	0	<1
Water (R-718)	0	<1
Carbon dioxide (R-744)	0	1

III. WINDOW AIR CONDITIONER

A window air conditioner is a system that cools space to a temperature lower than the surroundings. To accomplish this, heat must be removed from the enclosed space and dissipated into the surroundings. However, heat tends to flow from an area of high temperature to that of a lower temperature. During the cycle, a substance called the refrigerant circulates continuously through four stages. The first stage is called Evaporation and it is here that the refrigerant cools the enclosed space by absorbing heat. Next, during the Compression stage, the pressure of the refrigerant is increased, which raises the temperature above that of the surroundings. As this hot refrigerant moves

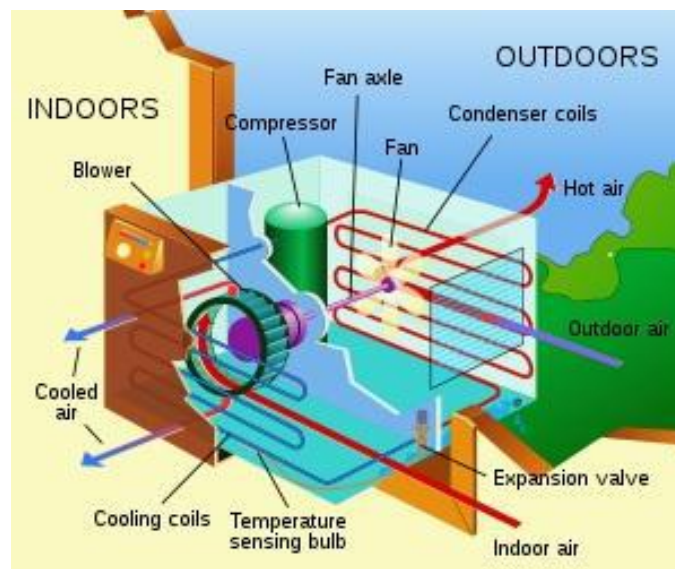


Figure 1. Construction of a window air conditioner [6]

through the next stage, Condensation, the natural direction of heat flow allows the release of energy into the surrounding air. Finally, during the Expansion phase, the refrigerant temperature is lowered by refrigeration effect. This cold refrigerant then begins the Evaporation stage again, removing more heat from the enclosed space. A typical diagram of a window air conditioner which works according to the process explained above is shown in the Figure 1.

Window air conditioner works on the principle of vapour compression refrigeration system. The refrigerant is a heat carrying medium which during the cycle (that is compression, condensation, expansion and evaporation) in the refrigeration system absorb heat from a low temperature source and discard the heat so absorbed to a higher temperature sink. The suitability of a refrigerant for a certain application is determined by its physical, thermodynamic, chemical properties and by various practical factors. There is no one refrigerant which can be used for all types of applications. If one refrigerant has certain good advantages, it will have some disadvantages also for a particular application. Hence, a refrigerant is chosen which has greater advantages and less disadvantages.

IV. LITERATURE REVIEW

S. Devotta et. Al [7] evaluated performance of HC-290 on a 5.13 kW window air conditioner designed for HCFC-22. They found that HCFC-22 gave a cooling capacity of 5.085 kW for the lower operating conditions and 4.111 kW for the higher operating conditions. The power consumed with HC-290 was lower by 12.4–13.5%. COP of HCFC-22 was 2.41 for the lower operating conditions and 1.76 was for the higher operating conditions. For HC-290, COP was

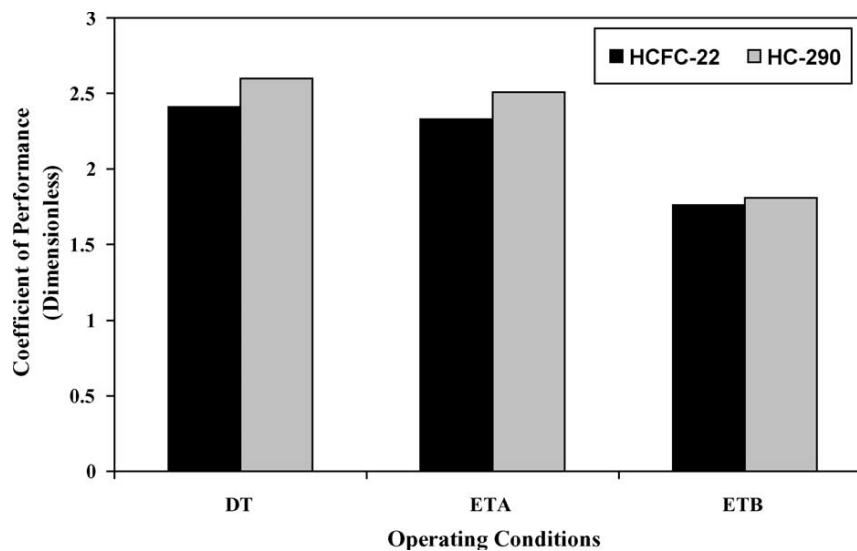


Figure 2. COPs of HCFC-22 and HC-290 for various operating conditions

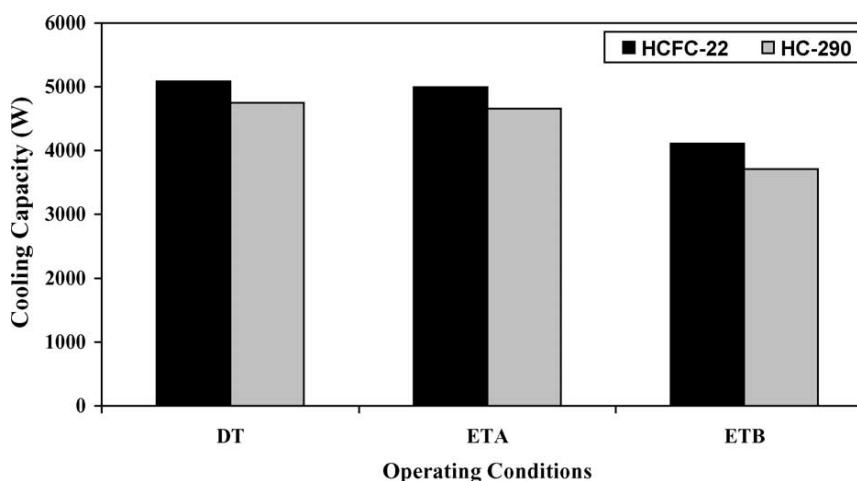


Figure 3. Cooling capacities of HCFC-22 and HC-290 for various operating conditions

7.9% higher for the lower operating conditions and 2.8% higher for the higher operating conditions. Figure 2 showed COPs of HCFC-22 and HC-290 for various operating conditions. COP of HC-290 was higher for all the tests because of the lower power consumption by the compressor. Test results showed that HC-290 had 6.6% lower cooling capacity for the lower operating conditions and 9.7% lower for the higher operating conditions with respect to HCFC-22. Figure 3

showed Cooling capacities of HCFC-22 and HC-290 for various operating conditions. The power consumed by the system with HCFC-22 was in the range 2111–2338 W. The discharge pressure of HCFC-22 was 2514.45 kPa for the lower operating conditions and 3072.92 kPa for the higher operating conditions. HC-290 had lower discharge pressures than HCFC-22. The discharge pressure of HC-290 for all operating conditions varied in the range 13.7–18.2% lower than HCFC-22.

D.B. Jabaraj et. Al [8] experimented on study of the behaviour of HFC407C/HC290/HC600a blend refrigerant mixture in a window air conditioner. Experiments were conducted for mixtures containing 10% and 20% HC blend (by weight) with HFC407C. These two mixtures were designated subsequently as M10 and M20, respectively. The compressor power of M20 and M10 were found to be 1.25–1.45% and 2.29–2.65%, respectively, higher than that of HCFC22, whereas the refrigerating effect of M20 and M10 were found to be

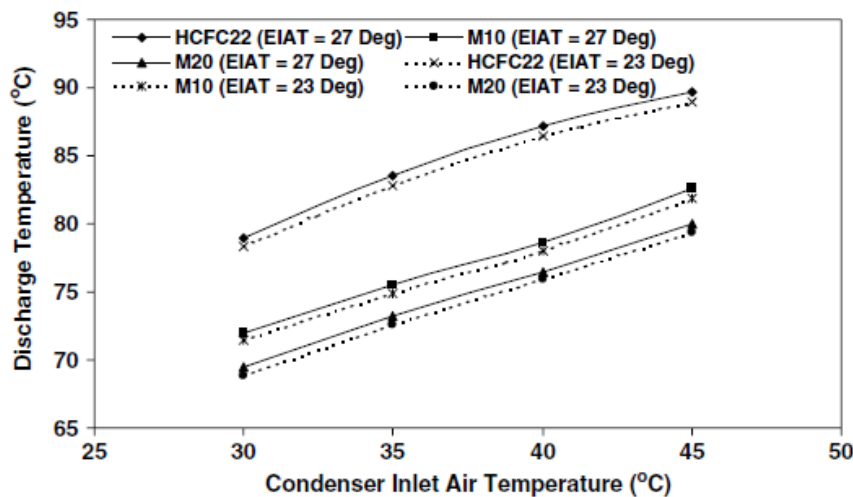


Figure 4 .Variation of discharge temperature with condenser inlet air temperature

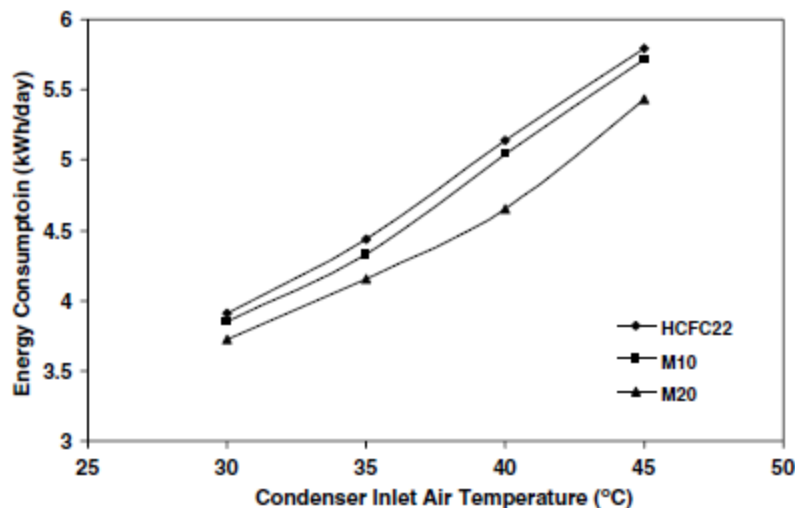


Figure 5. Variation of per day energy consumption with condenser inlet air temperature

9.54–12.76% and 4.02–5.85%, respectively, higher than that of HCFC22. The actual COP of M20 and M10 were found to be 8.19–11.15% and 1.68–3.23%, respectively, higher than that of HCFC22. The discharge temperatures of the compressor for M10 and M20 were 7.95–9.81% and 10.79–12.37%, respectively, lower than that of HCFC22. Figure 4 showed Variation of discharge temperature with condenser inlet air temperature. It was noticed that with the increase in the HC blend in the refrigerant mixture, the discharge temperature was reduced. The per day energy consumption of M10 and M20 were 1.31–2.5% and 4.83–9.46%, respectively, lower than that of HCFC22. Figure 5 Variation of per day energy consumption with condenser inlet air temperature. The fact that POE oil can be dispensed with by using the HFC407C/HC blend refrigerant mixture in the place of HFC407C is a significant finding in this work. They concluded that the mixtures demanded lengthening of the condenser by 19% in order to maintain the discharge pressure within acceptable limits.

S. Devotta et. Al [9] analysed performance of a 1.5 TR window air-conditioner, retrofitted with R-407C, as a substitute to HCFC-22. Cooling capacity of R-407C was lower in the range 2.1–7.9%. Power consumption of air

conditioner with R-407C was higher in the range 6–7%. COP of R-407C was lower in the range 8.2–13.6%. Discharge pressures of R-407C were higher in the range 11–13%. Pressure drops of R-407C were always lower.

D.B. Jabaraj et.al [10] evolved an optimal composition of HFC407C/HC290/HC600a mixture as an alternative to HCFC22 in window air conditioners. The HC percentage was also varied from 10 to 25% in steps of 5%. The new refrigerant mixtures demand longer condenser length to decrease the high discharge pressure matching with HCFC22 systems and hence the length has been increased while testing the mixtures. This also resulted in better heat transfer in condenser. Among the mixtures M20 is characterized with maximum

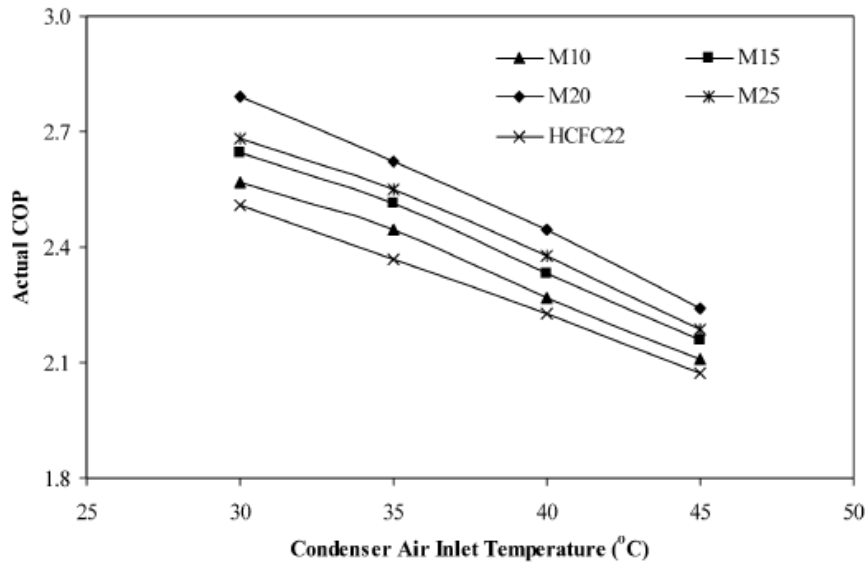


Figure 6. Variations of actual cop with condenser inlet air temperature at 27 °C evaporator inlet air temperature

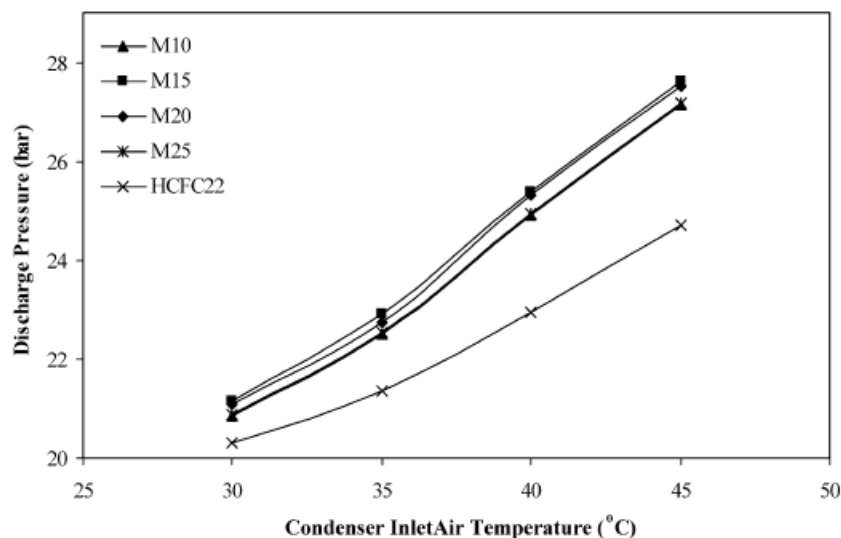


Figure 7. Variations of discharge pressure with inlet air temperature at 27 °C evaporator inlet air temperature

refrigeration capacity. It is observed that the improvement in refrigeration capacity of M20 mixture is 9.54 to 12.76% higher than HCFC22 at the various condenser inlet air temperatures. It is to be noted that, among all the mixtures the improvement in COP of M20 over HCFC22 was the maximum at all evaporator inlet air temperatures and is found to be 10 to 13.49% for 35 °C condenser inlet air temperature. Figure 6 showed Variations of actual cop with condenser inlet air temperature at 27 °C evaporator inlet air temperature. Thus M20 is found to be better in all the room temperature conditions. For M20 the discharge pressure is found to be 3.73 to 11.46% higher than that of HCFC22 for different condenser inlet air temperatures. Figure 7 Variations of discharge pressure with inlet air temperature at 27 °C evaporator inlet air temperature. Pressure ratio for M20 was the lowest and was found to be 3.56 to 4.97% lower than that of HCFC22 for various condenser inlet air temperatures. The performance analysis revealed that the new refrigerant mixture performed better than that of HCFC22.

K. Senthil Kumar et. Al [11] developed an eco-friendly refrigerant mixture HCFC-123/HC-290 with negligible ODP and GWP values that is nearly equivalent to R12 in its performance. Using REFPROP for analysis, they found that

the performance parameters for a mixture containing 70% R123 and 30% R290 were near matching with R12. They concluded that actual COP of Mix7/3 is higher than that of R12 for calorimeter temperature ranging from 1 to 25 °C. Figure 8 depicted comparison of Mix 7/3 COP with R12. The compressor discharge temperature of Mix7/3 is 5–22 °C cooler than the baseline test conducted with R12. The temperature and pressure variation of Mix7/3 is similar to that of R12, hence no modification in the R12 system is necessary. The overall performance of Mix7/3 is superior to that of R12 at all evaporator conditions.

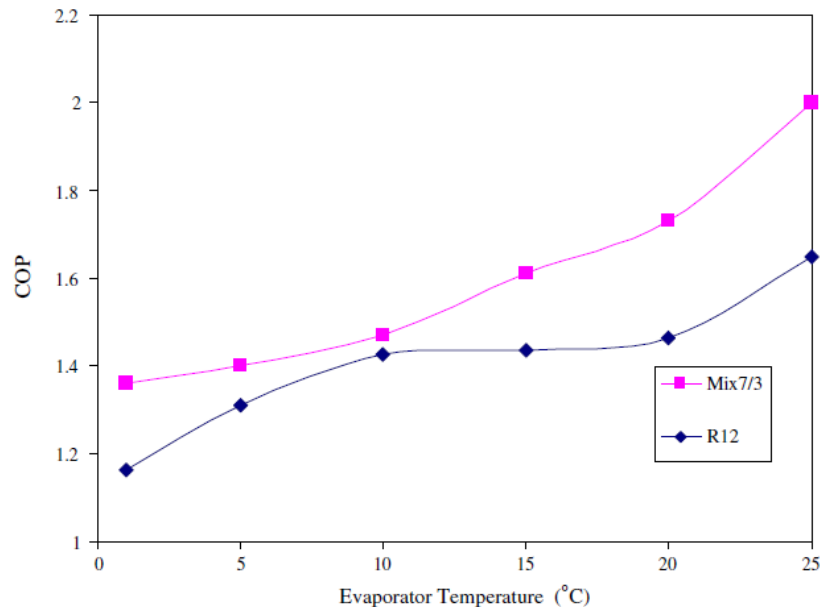


Figure 8. Comparison of Mix 7/3 COP with R12

Bukola Olalekan Bolaji [12] was carried out experiment to investigate the performance of R22 and its ozone-friendly alternative refrigerants (R404A and R507) in a window air-conditioner. The average compressor power of the system obtained using R507 and R404A were 6.5% lower and 7.2% higher than that of R22, respectively. Among the investigated refrigerants, R22 had the lowest discharge temperature, closely followed by R507 with average value of 4.2% higher, while that of R404A was 15.3% higher than that of R22. At the same ambient air temperature, the refrigeration capacity obtained from R507 retrofitted system is higher than those obtained from R22 and R404A. The average refrigeration capacity of R507 is higher by 4.7%, while that of R404A is lower by 8.4% than that of R22. The result of COP showed that R507 has the highest COP than those of R22 and R404A at any ambient air temperature. Compared with R22, the average COP of R507 increased by 10.6%, while that of R404A reduced by 16.0%.

J.H. Wu et al [13] An original R22 wall room air conditioner with a cooling capacity of 2.4 kW and energy efficiency ratio (EER) of 3.2 is retrofitted with a compressor of a 20% larger displacement to charge R290 and R1270 for performance experiments. The results showed that for R1270, only adopting a same kind Mineral lubricant of higher viscosity would supply 2.4% higher cooling capacity and 0.8% higher EER than those of the original R22 system under normal condition. Besides, the results showed that the use of the compressor of a larger displacement leads to increase in cooling capacity by 8.9% and 15% for R290 and R1270, respectively, but decrease in EER by 8.5% and 1.6% due to 18.9% and 16.8% higher power consumption when compared the cases without changing the compressor. In addition, the cooling capacity for R1270 was 13.9% higher than that for R290 and EER is only 1.7% lower when the compressor of a larger displacement was used. The R1270 system has great increase in cooling capacity and negligible decrease in EER.

V. CONCLUSION

From Literature review, Conclusions are made as under.

- COP of HC-290 is higher in the range 2.8–7.9%. Discharge pressure, Pressure drops of HC-290 are lower in the range than HCFC22. HC-290 performs better than that of HCFC22.
- With the increase in HFC407C/HC290/HC600a blend refrigerant mixture, the discharge temperature was reduced and COP of the system was found to be improving. New refrigerant M20 (HFC407C/HC290/HC600a mixture) performs better than that of HCFC22. The reliable life of the compressor is likely to be longer. This mixture demands lengthening of the condenser by 19% in order to maintain the discharge pressure within acceptable limits.
- Retrofitting with R-407C is an option to extend the life of air conditioning units, although the performance is slightly poorer.

- The temperature and pressure variation of Mix7/3 (70% R123 and 30% R290) is similar to that of R12, hence no modification in the R12 system was necessary. The overall performance of Mix7/3 is superior to that of R12 at all evaporator conditions studied.
- R1270 system with the compressor of a larger displacement has better performance with negligible loss in EER and great increase (13.9-17.6%) in cooling capacity (or 11.1% in cooling capacity per unit mass refrigerant) when compared to R290 system.
- R507 retrofitted window air conditioning system has closed performance characteristics to R22 with better (lower) compressor power and energy consumption, and higher refrigeration capacity and COP than both R22 and R404A.

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