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HFC-161 as an alternative to HCFC-22 in Air Conditioner

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Abstract

This paper discusses the suitability of HFC-161 over other refrigerants. Apart from having zero ODP and GWP value of 12, HFC-161 refrigerant can prove a promising alternative to HCFC-22 and various other HCFC refrigerants facing the fate of phase out. Various results are obtained on the basis of COP, discharge temperature, cooling capacity and power consumption. The general finding shows that HFC-161 refrigerant gives better COP, increased refrigeration effects and lower discharge temperatures. The flammability of HFC-161 needs to be addressed while using in air conditioner. A 1.5 TR capacity DC inverter operated air conditioner is to be tested in psychometric test laboratory for Capacity rating and Power consumption test.

Keywords: Alternate Refrigerants, HFC-161, HCFC-22, GWP, COP, Refrigeration effect, Discharge temperature, Power consumption.

1. Introduction

Due to the environmental concerns [Ozone depleting potential (ODP) and global warming potential (GWP)] of existing refrigerants, industry and researchers in this field are in search of long term solutions. CFCs and HCFCs refrigerants have been banned in developed countries and gradually phased out in developing countries as required by the Montreal Protocol (1987).

In refrigeration and air conditioning industries, the HCFC-22 (replaced by HFC-32) widely used is ozone depleting substance with ODP of 0.055 and global warming potential of 1800. The HCFC-22 has been phased out in developed and developing countries. The HCFC-22 was replaced by alternative HFC-32 but it has a global warming potential of 675 and the high discharge temperature of HFC-32 directs to use lubricating oil for compressor. So there is a need to search an alternative to HCFC – 22 and HFC-32 in ACs.

In such scenario, ethyl fluoride or HFC-161 with zero ODP and GWP value of 12 is gaining rapid importance. Not in use, till recently, due to its inflammable nature, it is now proved that along with inhibitors, HFC-161 can prove to be an important alternative refrigerant. The LFL of HFC-161 is 3.8% by volume.

DC-Inverter operated AC is used instead of Constant speed AC. The DC Inverter units have a variable-frequency drive that comprises an adjustable electrical inverter to control the speed of the electromotor, which means the compressor and the cooling / heating output.

The Thermo physical properties of HFC-161 shows that it is more energy efficient compared to HCFC-22. [12]

1.2. Properties of Refrigerants:-

The various thermo physical characteristics of HCFC-22, HFC-410 and HFC-161 are listed in Table 1. HFC-410 is also listed as it is now a days commonly used as an easily available alternate to HCFC-22. Among all the others, the GWP of HFC-161 is lower than that of HCFC-22, and HFC-410A and is almost negligible.

The molecular mass of HFC-161 is less than that of HCFC-22 and HFC-410A. The molecular mass of a refrigerant is directly related to the amount of charge required in the system. The lesser molecular mass implies lesser amount HFC-161 for charging of the system.

Table 1. Properties of HCFC-22, HFC-410A and HFC-161 [14]

Physical property	Unit	HCFC-22	HFC-410A	HFC-161
Molar mass	g/mol	86.5	72.6	48.06
Normal boiling point	∘ C	-41	-51.4	-37.6
Critical temp	∘ C	96.2	70.5	102.2
ODP	-	0.05	0	0
GWP_{100}	-	1000	2100	12
Lower flammability limit	kg/m^3	-	-	0.075
Burning velocity	Cm/s	-	-	38.3
Safety class		A1		A3

The critical temperature of HFC-161 is near to HCFC-22. The atmospheric life time of HFC-161 is just 76 days.

Advantages of using HFC-161

- The critical temperature of the refrigerant should be well above the condensing temperatures for easy condensation of vapour. It should have high critical temperatures and pressures. The new refrigerant has higher critical temperature and pressure compared to HCFC-22 and HFC-410A.
- HFC-161 has zero ozone depletion potential (ODP) and very low global warming potential of 12, while the HCFC-22 has a very high GWP of 1800 and HFC-410A has a higher GWP of 2100.
- The refrigerant should have high latent heat of vaporization since the evaporation of refrigerant produces refrigerating effect. HFC-161 has higher latent heat of vaporization of 421.3 KJ/Kg as compared to HCFC-22 of 233.7 KJ/Kg and HFC-410A of 256.7 KJ/Kg.

Disadvantages of using HFC-161

- Refrigerant should not be poisonous or injurious. It should also be non-irritating to the eyes and lungs. It should be non-toxic. HFC-161 has higher toxicity of 1800 ppm as compared to HCFC-22 with toxicity of 1000 ppm.
- The refrigerant should be non-inflammable and non-explosive. HFC-161 has an inflammable nature with lower flammability limit by volume of 3.8 %, while HCFC-22 is non-inflammable.

The Objective of this research is to study the properties of HFC-161 and develop & test DC inverter operated split air conditioner with HFC-161 as an alternative to HCFC-22.

To carry out the optimisation studies for HFC-161 for maximum EER and required capacity i.e. 5.2kW.

2. Literature Survey

Xuan et al. (2004) used a ternary mixture of HFC-161/HFC-125/HFC-143a (10/45/45% by weight) as a drop-in substitute for R-404a in refrigeration applications. The results showed that the coefficient of performance (COP) of HFC-161 mixture was nearly equivalent to R-404a for lower evaporating temperature of -40°C and for higher evaporative temperature of -23°C, the COP of the mixture was greater than that of R-404a. The near azeotropic ternary mixture has lower temperature glide than for R-404a.

Yingwen Wu et al. (2012) carried out the theoretical performance of HFC-161, HCFC-22 and R-290. The experimental performance of HFC-161 and HCFC-22 was also carried out in a 3.5 kW residential heat pump air conditioner. During simulation, it was observed that the Energy Efficiency Ratio (EER) of R161 increased by 2% compared to HCFC-22. However, the cooling capacity of HFC-161 reduced by 9.2% compared to HCFC-22. During experimentation, it was found that R161 had better cooling capacity, higher EER or COP and lower discharge temperature than that of HCFC-22.

More et al. (2014) carried out the theoretical cycle performance of HCFC-22 and HFC-161 for the evaporating temperature range of -15°C to 10°C. In this performance, the discharge temperature for R161 is lower than that of R22 by 11.6% at the evaporating temperature of -15°C to 9% when the evaporating temperature is increased to 10°C. Also, the refrigerating effect for HFC-161 is 87.4% higher than that of HCFC-22 at 10°C evaporating temperature. However, the power requirement for HFC-161is higher than for HCFC-22 by 45% at the evaporating temperature of -15°C to 61% at the evaporating temperature of 10°C. Hence, the COP for R161 is higher than that of R22 by 29% at the evaporating temperature of -15°C and 15.3% at the evaporating temperature of 10°C. Improvement in COP with HFC-161 can be accomplished by reduction of power requirement which is much higher compared to HCFC-22.

Hatkar et al. (2015) compared the performance of the binary mixture of HFC-134a and HFC-161 (40/60% by wt.) with that of HFC-134a. For various temperature combinations, the COP of HFC-161 mixture and HFC-134a were identical. For identical COP, the specific refrigeration effect of the HFC-161 mixture was 37% more than that of HFC-134a, while the volumetric refrigeration effect of the HFC-161 mixture was 32.6% more than that of HFC-134a. However, the discharge temperature of HFC-161 mixture was more than for HFC-134a by 2.01%.

Padalkar et al. (2015) carried out the performance of HCFC-22 and HFC-161 in a split type air conditioner with a nominal cooling capacity of 5.2 kW that was originally designed for HCFC-22. It was observed that the cooling capacity of HFC-161 was 10.1 % lower than that of HCFC-22. However, the (EER) was 19.7% higher than that of HCFC-22. With the use of modified capillary, the cooling capacity of HFC-161 was observed to be 7.1% lower than that of HCFC-22. However, the EER of HFC-161 was observed to be 17.7% higher than that of HCFC-22

3. Simulation

The test conditions considered for performance evaluation of air conditioner was as per Indian standard IS1391 part 1. These are also prescribed by Bureau of Energy Efficiency (BEE), India. The test unit has been procured and assembled by first group of student involved. Test lab are prepared and a few instruments were calibrated before testing (under supervision of experts from Cosmic Refrigeration Pvt. Ltd. And Faculty Advisor). Finally test was conducted in Psychrometric Test Laboratory at Cosmic Refrigeration Pvt. Ltd. Initially HCFC-22 test were conducted for full capacity, half capacity and minimum capacity by maintaining the room conditions as given in the Table 1 below.

Table 2. Test conditions for labelling variable capacity Air conditioners [8]

Temperature*		Cooling Capacity Test as per IS 1391 (Part 1 & Part 2)	Power Consumption Test as per IS 1391 (Part 1 & Part 2)
Outdoor	Indoor	At 35°C	
35°C DBT and 24°C WBT	27°C DBT and 19°C WBT	Standard cooling at Full Capacity	Standard cooling at Full Capacity
		Standard cooling at 50% of full capacity	Standard cooling at 50% of full capacity

Table 3. Test Facility of Psychrometric test Laboratory[8]

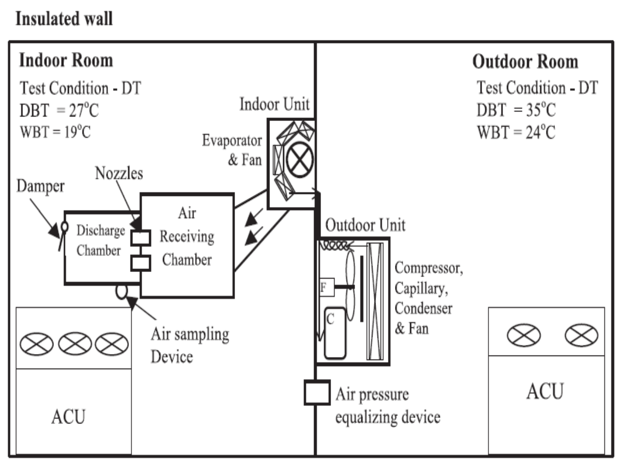

Table 3 present the schematic of test facility provided by Cosmic Refrigeration Pvt. Ltd, Pune.

4. Result and Discussion:- In the Simulation for HCFC-22 and HFC-161 at various load capacity, the following graphs are made with respect to the various parameters. The graphs which are considered gives more variation for the following parameters

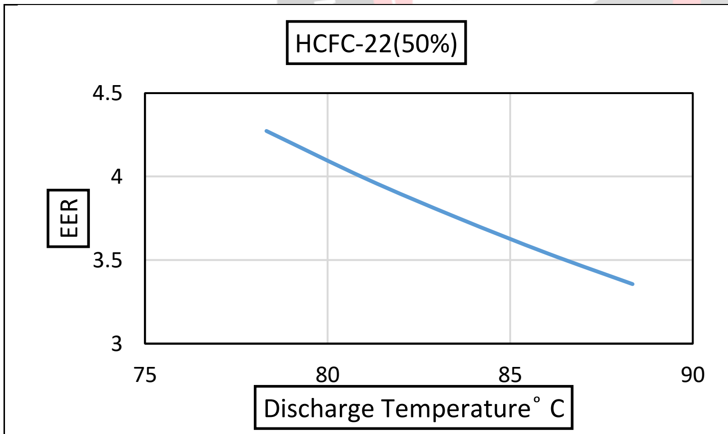

Fig. 4.1 - EER vs Discharge temperature

In the simulation for HCFC-22 at 50% load capacity it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, EER is gradually decreasing ,Comparatively HCFC-22 at 100% load capacity it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, EER steeply decreases

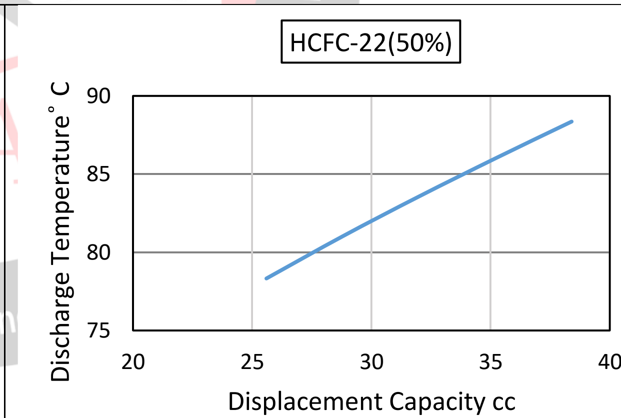

Fig. 4.2- Displacement Capacity vs Discharge temperature

In the simulation for HCFC-22 at 50% load capacity it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, Discharge temperature first increases gradually and then steeply increases. Comparatively HCFC-22 at 100% load capacity it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, whereas Discharge temperature initially remains the same, then decreases slightly and increases steeply.

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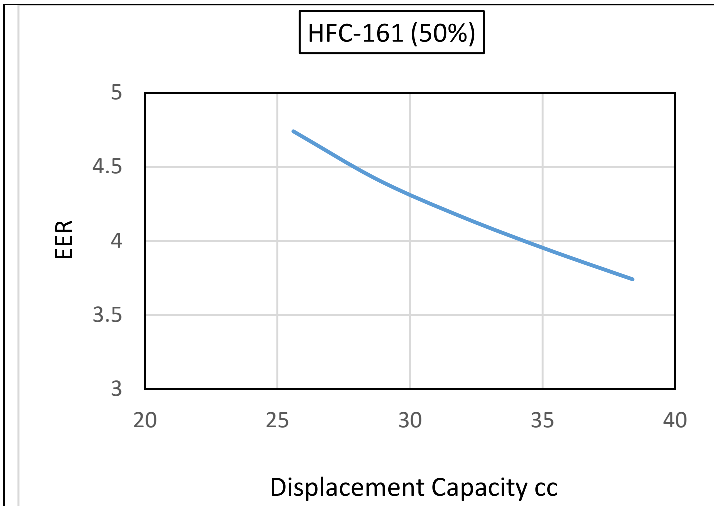


Fig. 4.3 – EER vs Displacement capacity

In the simulation for HFC-161 at 50% load capacity, it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, EER is gradually decreases. Comparatively HFC-161 at 100% load capacity, it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, EER is gradually decreases.

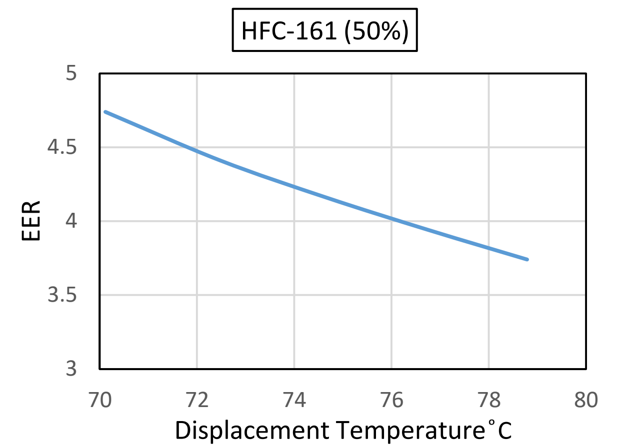


Fig. 4.4 – EER vs Displacement Temperature

In the simulation for HFC-161 at 50% load capacity, it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, Discharge temperature is gradually increasing. Comparatively HFC-161 at 100% load capacity, it is observed that EER is gradually decreasing whereas Discharge temperature slightly increases.

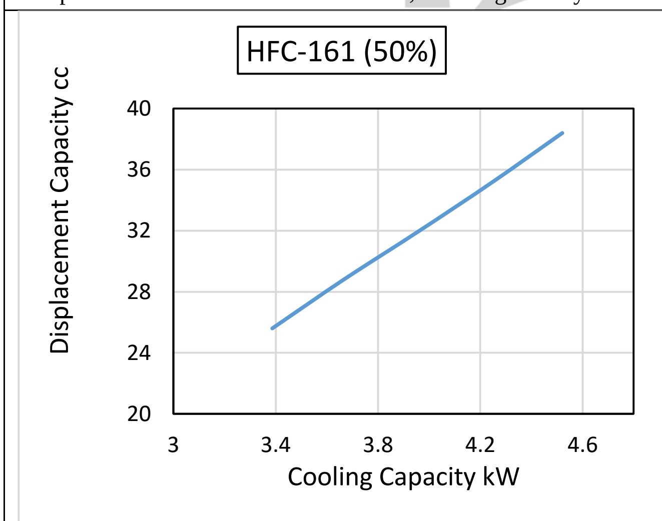


Fig. 4.5 – Cooling capacity vs Displacement capacity

In the simulation for HFC-161 at 50% load capacity it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, Cooling capacity increase gradually. Comparatively HFC-161 at 100% load capacity, it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, Cooling capacity increase gradually.

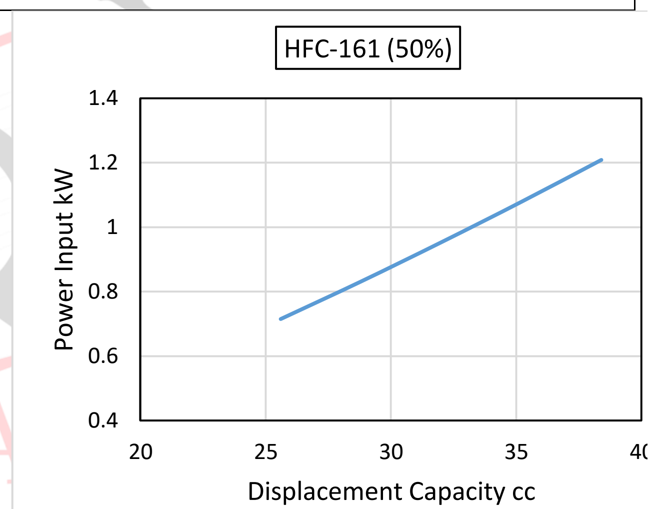
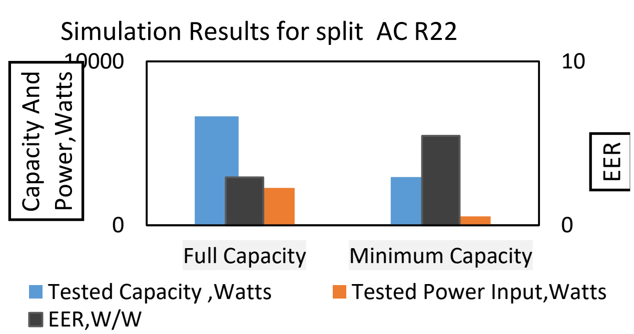


Fig. 4.6 – Displacement capacity Power input

In the simulation for HFC-161 at 50% load capacity it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, Power input increase gradually. Comparatively HFC-161 at 100% load capacity, it is observed that when Displacement capacity of the compressor is varied from 25 cc to 40 cc, Power input increase gradually.

The test results of HCFC-22 for full capacity, minimum capacity were noted and mentioned in Table 4.

Table 4. Test results for split AC



- EER at full capacity is 53.47% of EER at minimum capacity.
- Power input at minimum capacity is 23.62% of Power input at full capacity.

5. Conclusions:-

Based on findings by various researchers, HFC-161 can be a potential replacement to HCFC-22 in air conditioner. The studies show that the zero ODP value and GWP value of 12 of HFC-161 makes it an attractive alternative refrigerant.

Based upon the study,

1. COP increases with increase in evaporating temperature.
2. COP increases with increase in superheat.
3. COP decreases with increase in condensation temperature.
4. Power consumption increases with increase in condensation temperature.
5. Power consumption decreases with increase in evaporating temperature.

After carrying out simulations in the psychometric simulations laboratory which is to be conducted in April 2018, we will come to the conclusion on why the new refrigerant HFC-161 is a better choice in air conditioning system.

6. Nomenclature:-

HFC	Hydrofluorocarbon
ODP	Ozone Depleting potential
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
COP	Coefficient of performance
DC	Direct Current
CFC	chlorofluorocarbon
AC	Air conditioner
LFL	Lower flammability Limit
EER	Energy Efficiency Ratio
BEE	Bureau of Energy Efficiency
DBT	Dry Bulb Temperature
WBT	Wet Bulb Temperature
ACU	Air Conditioning Unit

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