SIMULATED PERFORMANCE OF HFC-32 IN ROOM AIR CONDITIONER

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ABSTRACT:

HFC-32 is being considered as an alternative for HCFC-22 in room air conditioners. HFC-32 is non ODS. Its GWP is 675. HFC-32 is classified under A2L under latest ASHRAE 34 standard. The volumetric capacity of HFC-32 is about 60% higher compared to HCFC-22. HFC-32 gives lower pressure drop in heat exchangers than both HCFC-22. The pressure drop for HFC-32 in evaporator is 36% lower than HCFC-22. In condenser, pressure drop are much lower than pressure drop in evaporator. The discharge temperature of HFC-32 is higher than HCFC-22.

In this paper, the simulated performance of split air conditioners (SAC) using HFC-32 with nominal cooling capacity of 5.1 kW was studied. The simulation has been carried out for SAC using test conditions prescribed in Indian Standards IS 1391 (1992) Part I. The simulation has been carried out for variation in compressor capacity, capillary, and exchanger tubing. The results showed that COP improvement for HFC-32 air conditioner is about 8% when 5 mm tube OD was used for condenser. There is marginal improvement in COP when capaillary optimization was performed.

Keywords: HFC-32, HCFC-22, air conditioner, simulation.

[1] INTRODUCTION

HCFC-22 is predominantly used in room air conditioner since a long time. As per the accelerated phase out schedule of Montreal Protocol, HCFC-22 has to be replaced with some alternative fluid. The air conditioner market is growing largely in past few years and growth rate expected is more than 30% in next 4-5 years. Most of the non-Article 5 countries already replaced HCFC-22 with HFCs mainly R410A and R407C due to early phased out schedules. R407C has similar operating characteristic as that of HCFC-22 and considered as retrofit without much modifications in existing equipment [4]. However it has high temperature glide around 7°C whereas R410A has temperature glide about 0.1°C [8]

HFC-32 is non-ODS. Its GWP is 716 is this value is about 1/3rd of R-410A. HFC-32 is mildly flammable refrigerant and it is in class 2L as per ASHRAE 34 standard. Toxicity class for HFC-32 is similar to that of HCFC-22 [8]. HFC-32 has better energy efficiency compared to HCFC-22. Many researchers has evaluated HFC-32 performance in air conditioners. Yajima et al. [3] experimentally compared the performance of HFC-32 and R-410A in 16 kW capacity inverter split air conditioner. The result shows that COP of HFC-32 is about 10% and 7% higher than R410A for rated, half rated capacity respectively. It was concluded that TEWI due to HFC-32 can reduced to 18% compared to R-410A. The author recommended that HFC-32 is midway solution from viewpoint of safety, energy and environment criteria. Pham et al. [6] conducted the drop-in test with HFC-32 in R-410A air conditioner following the AHRI 210/240 Standard. HFC-32 capacity and EER was 3-4% higher and 1-1.5% lower respectively compared to R-410A. It has been recommended that the smaller size tubing and microchannel heat exchangers gave more benefit in case of HFC-32 compared to R-410A. Xu et al. [9] showed that R32 is an excellent alternative to R-410A in terms of performance. The different system components need to be optimized for better performance. The author also recommended that two-phase injection to the compressor at extreme conditions can also be utilized to reduce the compressor discharge temperature.

[2] THERMOPHYSICAL PROPERTIES

Thermophysical properties of HFCFC-22 and HFC-32 are compared and analyzed in this section. The refrigerant properties database are used from EES v9.091[5]. Figure 1 presents the vapour pressure of HFC-32 and

HCFC-22. The vapour pressure of HFC-32 is higher than HCFC-22. Latent heat of HFC-32 at NBP is about 63% higher HCFC-22. HFC-32 has high heat transfer coefficients in heat exchangers. The volumetric cooling capacity of HFC-32 is about 60% higher than HCFC-22. Higher volumetric cooling capacity of HFC-32 indicates smaller size compressor in comparison to HCFC-22. The discharge temperature with HFC-32 would be higher as compared to both HCFC-22 and R-410A. Xu et al. [7] conducted experimental study in order to reduce higher discharge temperature with HFC-32 using vapour injection. The results showed that the discharge temperature ws reduced in the range of 10 ^{o}C to 20 ^{o}C. The lower liquid and vapour viscosity of HFC-32 offer lower pressure drop in heat exchangers than HCFC-22. The theoretical pressure drops for HFC-32 in exchangers is 36% lower than HCFC-22 at similar operating conditions. Lower flammability limit (LFL) of HFC-32 is 0.306 kg/m3 by mass. Allowable charge of flammable refrigerants specified in EN 378 [2]. Maximum charge of HFC-32 is greater than 4 kg for air conditioner with 5.2 kW capacity.

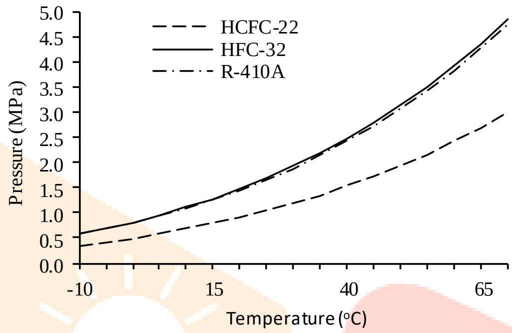

Figure: 1. Saturation temperature vs pressure of HCFC-22, HFC-32, and R-410A.

[3] THE SYSTEM SIMULATION

In this study, a typical 5.2 kW capacity split air conditioner designed for HCFC-22 was selected for performance evaluation with HFC-32. The simulation has been done for HFC-32 and its performance is compared with experimental. The input data required for system simulation were collected from the original equipment and compressor manufacturers. [**Table-1]** presents the input data used during simulation of HFC-32 unit. Initially an existing system for HCFC-22 (except compressor) has been considered to validate the simulation tool. BIS 1391 (1992) [1] prescribes the room conditions to be maintained during capacity rating test conditions. The similar room conditions were considered during simulation. The simulated results with HCFC-22 are with in ±3.5% with the experimental.

Table 1. Input data used for simulation of HFC-32 system.

Compressor	Condenser	Evaporator	Expansion device
EER 2.92, Cooling capacity 4880 W, Power input 1670 W Oil used 0.46 L	Tube OD 7 mm, Tube spacing 19 mm, Tube pitch 22 mm, Heat transfer area 0.49 m2, Al Fins, 19 FPI, 0.1 mm thick	Tube OD 7 mm, Tube spacing 12.7 mm, Tube pitch 21 mm, Heat transfer area 0.31 m2, Al Fins, 18 FPI, 0.1 mm thick	0.07” x 1.375 m length

After validating the baseline performance of HFC-32 with experimental, some optimization study was carried out with various condenser area, evaporator area and capillary tubing. The condenser area variation obtained primarily by varying tube diameters to achieve the best possible performance. The following different cases are considered for simulation of HFC-32.

Case 1: Baseline HFC-32 with optimized charge
Case 2: HFC-32 system as in Case 1 except different capillaries
Case 3: HFC-32 system as in Case 1 except different condensers
Case 4: HFC-32 system as in Case 1 except different evaporators
Case 5: HFC-32 system as in Case 1 except different compressors

[4] RESULTS AND DISCUSSION

[Figures-2] to **[Figures-5]** show the COP, cooling capacity, power consumption, and refrigerant charge for various cases considered. The constant evaporator superheat of 3 K was maintained during all simulated cases to ensure vapour before compressor.

Capillary Variation: **[Figure-2]** shows the simulated performance for various capillary lengths. The baseline COP with HFC-32 is 3.35. The capillary variation in length considered during simulation is 92%, 107% and 115% that of original capillary used in HCFC-22 system. Capillary diameter was, 1.77 mm, is kept constant during simulation. Both Cooling capacity and COP was marginally improved when capillary length was 7% longer.

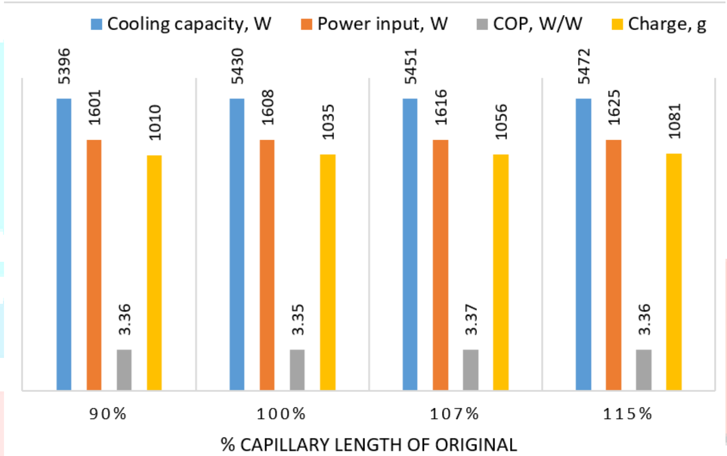

Figure: 2. COP, Cooling Capacity, Power input and Charge of HFC-32 for various % capillary lengths of original

Condenser tube size and spacing variation: In order to reduce charge of HFC-32, smaller diameter tubing was used without fall in COP**. [Figure-3]** presents the simulated performance for various condenser tube sizing. There is marginal fall in capacity and COP when 5 mm tube OD was used with condenser. Tube spacing and row spacing was adjusted when 5 mm tube OD was used. It is observed with marginal compromise in performance, there is saving in condenser material which will reduce cost. With 5 mm tube OD condenser, HFC-32 charge is reduced by 200 g.

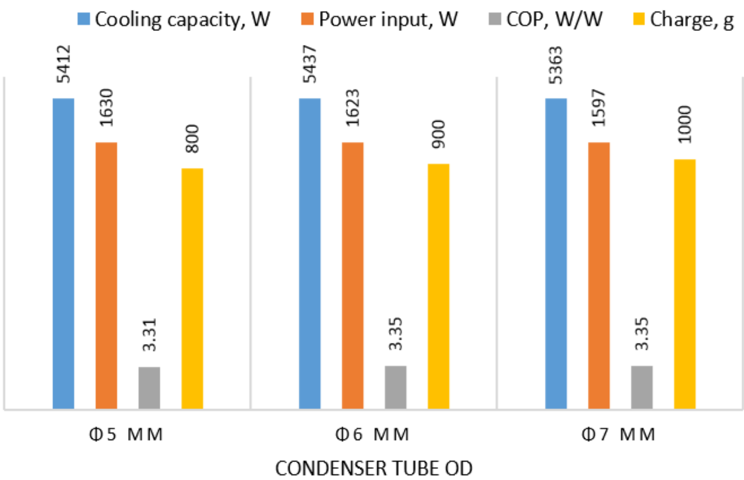

Figure: 3. COP, Cooling Capacity, Power input and Charge of HFC-32 for various condenser tube sizing

Evaporator tube size and spacing variation: [Figure-4] represents the simulated performance of evaporator tube sizing for 6mm, 7mm and 8mm tube ODs. It is observed that, there is increase in cooling capacity and marginal drop in COP when 6 mm tube OD was used for evaporator. Studies are conducted for several Tube spacing and row spacing and optimized results are plotted when 6 mm tube OD was used. It is found that with small compromise in performance, there is considerable saving in terms of reduced cost for evaporator material. With 6 mm tube OD evaporator, HFC-32 charge is also reduced from 1000g to 800 g.

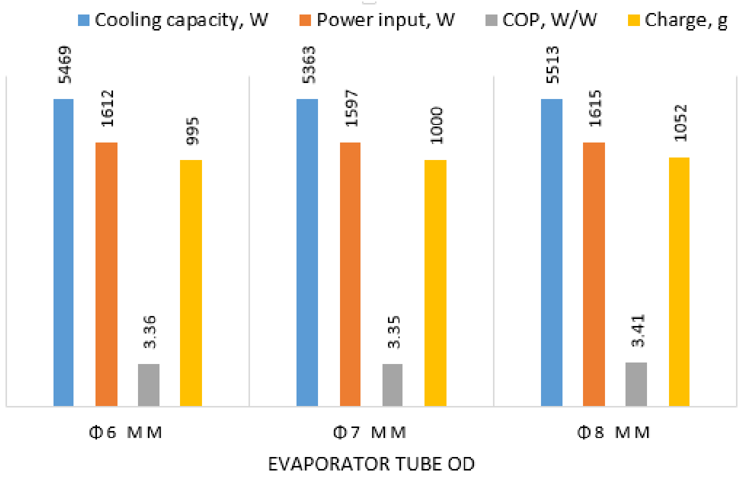

Figure: 4. COP, Cooling Capacity, Power input and Charge of HFC-32 for various evaporator tube sizing

Compressor capacity variation: The improvements in performance is possible with decrease in compressor's rated capacity and thus attempts are made to change the rating capacity of compressor and results are obtained for 90 %, 95% and 100% compressor capacity as shown in **[Figure-5]**. It is clear that, the effects of decrease in power input is more dominant than decrease in cooling capacity as the maximum COP is obtained at 90% compressor capacity with reduction in HFC-32 charge to 990 g.

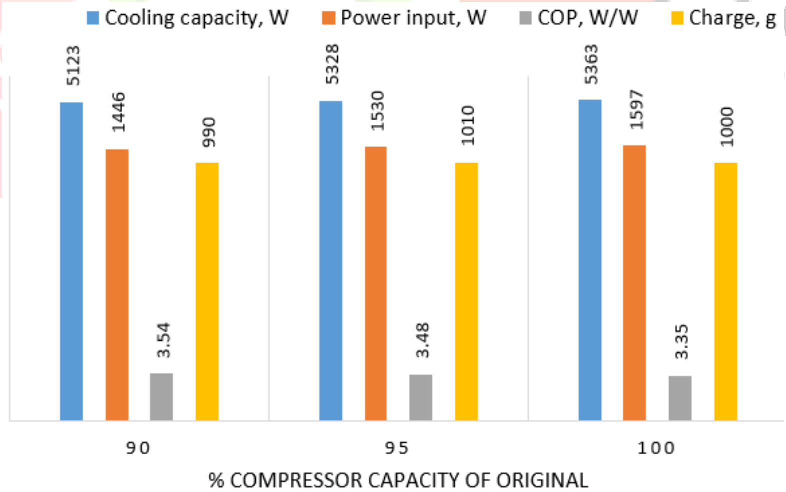

Figure: 5. COP, Cooling Capacity, Power input and Charge of HFC-32 for various compressor capacity

[5] CONCLUSIONS

HFC-32 is a promising alternative to HCFC-22 in air conditioner applications. In this study, computerised simulation studies were carried out with HFC-32 for various capillary lengths, condenser and evaporator tube sizes and compressor capacities. The simulation results shows that for HFC-32, power input decreases with reduction in rating capacity of compressor which improves COP. For all cases considered, 5mm OD condenser tube and 6 mm evaporator tubing gave better performance with nominal drop in cooling capacity but saves considerable amount in terms of space and material requirements. In the case of condenser with 5 mm OD, HFC-32 has charge of 800 g only which is in limit of EN378 and COP is 3.31 with minor loss of cooling capacity. COP improvement for HFC-32 air conditioner is about 8% when 5 mm tube OD was used for condenser. There is marginal improvement in COP when capaillary optimization was performed.

NOMENCLATURE

HCFC: Hydrochlorofluorocarbon
HFC: Hydrofluorocarbon
ODS: Ozone depletion substances
GWP: Global warming potential
LFL: Lower flammability limit
COP: Coefficient of performance
SAR: Split air conditioner
EN: European Nation
AHRI: Air conditioning, heating, refrigeration institute

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