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Low-GWP Refrigerant Evaluation in AC Systems for High Ambient Temperature Applications - Literature Survey for Impact of Varying Refrigerant Charge on AC System Performance – FY18 1st Quarter Milestone Report

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Low-GWP Refrigerant Evaluation in AC Systems for High Ambient Temperature Applications - Literature Survey for Impact of Varying Refrigerant Charge on AC System Performance

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Literature Survey for Impact of Varying Refrigerant Charge on AC System Performance (Regular Milestone)

Executive Summary

The report summarizes the findings of ASHRAE Research project 1173, by Purdue University to assess the impact of varying refrigerant charge on air conditioner (AC) system performance. This project tested six residential air conditioners with varying the system charge in a wide range, using TXV or fixed-orifice as the expansion device. In summary, the systems using fixed-orifices are much more sensitive to reduction of the system charge than using TXVs. The systems using fixed-orifices had noticeable performance degradations when reducing the system charge below 90% relative to the factory charge; the systems using TXVs experienced drastic performance penalties when decreasing the system charge below 80%. In the cases, the TXVs were all fully open and couldn't control the target superheat degree. In order to limit the system charge for lower-GWP refrigerants, without degrading the system performance much, the AC systems are recommended to use TXV and compact heat exchangers, i.e. micro-channel heat exchangers.

Impact of Charge Variation in Residential Air Conditioners

The new lower-GWP refrigerants mostly contain HFO refrigerants (R-1234yf or R-1234ze) and R-32. They are classified as A2L refrigerants, having minor flammability. It is necessary to limit the system charge inventory; sometime, even sacrifice the optimum performance with limiting the system charge to meet the safety regulation. The report summarizes previous studies for the impact of varying refrigerant charge on the system performance of residential air conditioners.

Purdue University [1] [2] conducted comprehensive laboratory investigations to assess impact of varying refrigerant charge on system performance of residential air conditioners. They extensively tested six residential air conditioners with varying the system charge inventory in a wide range. The six units used either thermo-expansion valve (TXV) or fixed-orifice, and covered three refrigerants, i.e. R-410A, R-22 and R-407C. The rated cooling capacities varied from 2.5-ton to 5-ton. They all used fin-and-tube indoor and outdoor heat exchangers. Table below summarizes the unit information.

Table 1: Six Residential AC Units for Varying System Charge

Unit	1	2	3	4	5	6
Refrigerant	R-410A	R-410A	R-410A	R-407C	R-22	R-22
Expansion	TXV	Fixed-orifice	Fixed-orifice	Fixed-orifice	Fixed-orifice	TXV
Rated capacity	3-ton	3-ton	3-ton	5-ton	2.5-ton	2.5-ton
Split or packaged	Split	Split	Packaged	Packaged	Packaged	Packaged

When changing the system charge, the units were evaluated at four ambient temperatures, i.e. 75°F, 82°F, 95°F and 115°F, and two indoor conditions, i.e. Wet - 80°F dry bulb/51% relative humidity; and Dry – 80°F/30% relative humidity.

Figures 1 illustrates EER ratios at various charge levels, relative to the EER obtained at the 100% system charge, having the same outdoor and indoor conditions. The 100% system charge (nominal level) was the factory charge recommended by the equipment manufacturer. Figures 2 illustrates capacity ratios relative to the air side capacity obtained at the 100% system charge, the same outdoor and indoor conditions.

It can be seen, the systems using fixed-orifices as the expansion device are much more sensitive to reduction of the system charge than using TXVs. In general, the systems using fixed-orifices had noticeable performance degradations when reducing the system charge below 90% relative to the factory charge; the systems using TXVs experienced drastic performance penalties when decreasing the system charge below 80%. In the cases, the TXVs were fully open and couldn't control the target superheat degree.

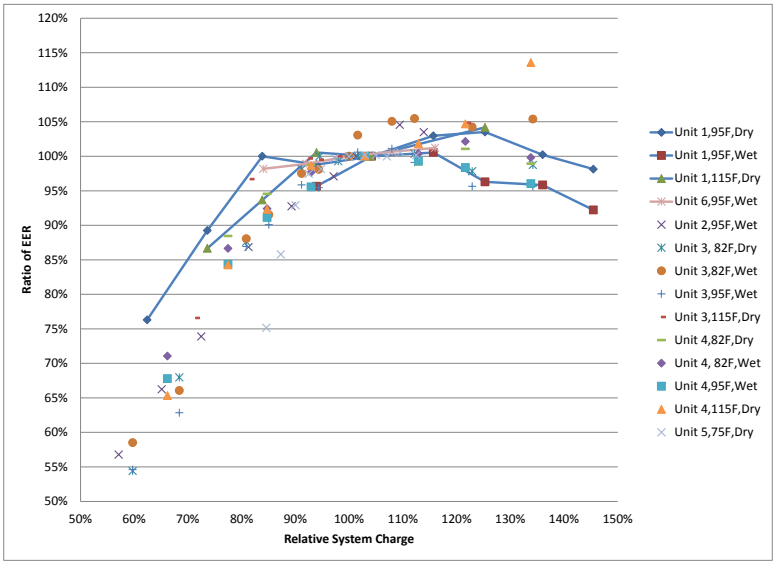

Figure 1: EER ratios as function of relative system charge in six residential AC units

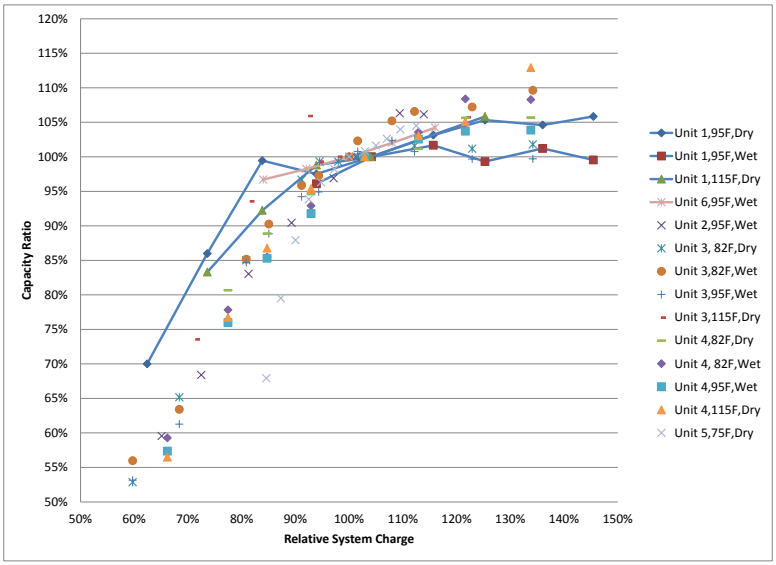

Figure 2: Capacity ratios as function of relative system charge in six residential AC units

References

[1] Bo Shen, EA Groll, JE Braun, 2006, Improvement and validation of unitary air conditioner and heat pump simulation models for R-22 and HFC alternatives at off-design conditions, - Final Report for ASHRAE Research Project 1173, 2006, Purdue University, West Lafayette, IN.

[2] Bo Shen, James E. Braun, Eckhard A. Groll, Improved methodologies for simulating unitary air conditioners at off-design conditions, International Journal of Refrigeration, Volume 32, Issue 7, 2009, Pages 1837-1849, ISSN 0140-7007.