Efficiency and Subcooling Variation with Refrigerant Charge for Unitary Air Conditioning Systems with TxV Expansion Device

Subtask 2.1B

Work Authorization # 6
Contract #400-09-001
Covering Tasks 3 Subtask 2

2013 RESIDENTIAL BUILDING ENERGY EFFICIENCY STANDARDS

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1. Introduction

1.1. This technical brief is presented in response to the proposal to widen the subcooling acceptance limits for HERS verification (of refrigerant charge) for TXV systems. The proposal is to change the acceptable range of subcooling to greater than 2°F and less than 8°F higher than the manufacturer's specified subcooling target. The proposal is presented in the CASE report prepared by Wilcox and Proctor and dated December 2010.

1.2. The justification is based on the impact of sensible EER. The authors do explain why sensible EER is used instead of EER based on the total system cooling capacity. Based on the two systems analyzed, the authors made the following conclusion: "As illustrated in Figure 9 the recommended range of acceptance limits the sensible efficiency effect to substantially less than 5%."

2. Experimental Data for Air Conditioning Systems with TxV

2.1. Laboratory test data were presented by Temple (2008) for variation of subcooling (SC), power, and total cooling capacity with refrigerant charge for several TxV systems. System information is provided in Temple (2008) and the source documents identified in the list of References. All the systems have fin-tube condenser coils.

2.2. Data Nomenclature: The performance data are presented primarily in the form of figures with the datasets being labeled as identified in the Glossary. An example dataset designation is "PA_SH_80/67/_". The test system is identified using a two or three character designation (e.g., PA). The performance parameter being presented is identified with a two-letter (or three-letter) designation as defined in the Glossary. Performance parameters include Superheat (SH), Subcooling (SC), and Indoor Temperature Difference (ITD). The test condition is identified as 80°F indoor air dry-bulb temperature and 67°F indoor air wet-bulb temperature in this example. A "_" in the outdoor air temperature location indicates a parametric study in outdoor air temperature. Other parametric studies are identified as indicated in the Glossary, e.g., "charge" indicates a parametric study in refrigerant charge.

2.3. In Figure 1 selected data are presented for the change in EER change as a function of the change in SC for different charge levels. The reference point is the nominal charge level at the indicated operating condition.

2.4. For the +8°F end of the proposed acceptance range (high charge) the impact is ±5% EER (EER based on total capacity) based on the data in Figure 1.

2.5. Considering the low charge (low subcooling performance) of Figure 1, it can be observed that the PA and OA3 systems do not have significant efficiency variation until the SC reaches a minimum value which corresponds to no (0) subcooling. For these systems the minimum of 2°F SC would result in less than 5% efficiency degradation. For the NI system the data are presented in Figure 2 as a function of the actual subcooling value. For this system a subcooling value of 2°F corresponds to an approximate EER degradation of 12% or sensible EER degradation of 8%.

3. Conclusions

3.1. The data presented are not in complete agreement with the CASE report statement that the “recommended range of acceptance limits the sensible efficiency effect to substantially less than 5%.” For the +8°F end of the acceptance range (high charge) the impact is ±5% EER (EER based on total capacity); however, one system had a 12% EER degradation or 8% sensible EER degradation at the 2°F subcooling low limit. The upper limit may be acceptable, but the lower limit can allow significant efficiency degradation.

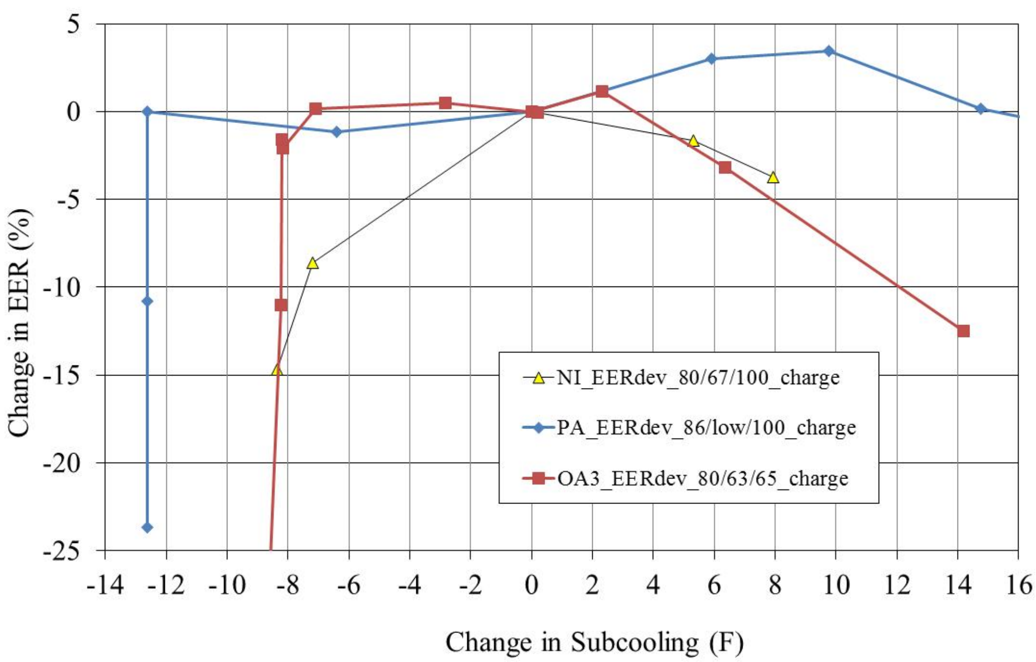

Figure 1. Change in EER and Subcooling with Refrigerant Charge – Experimental Data, TxV Systems

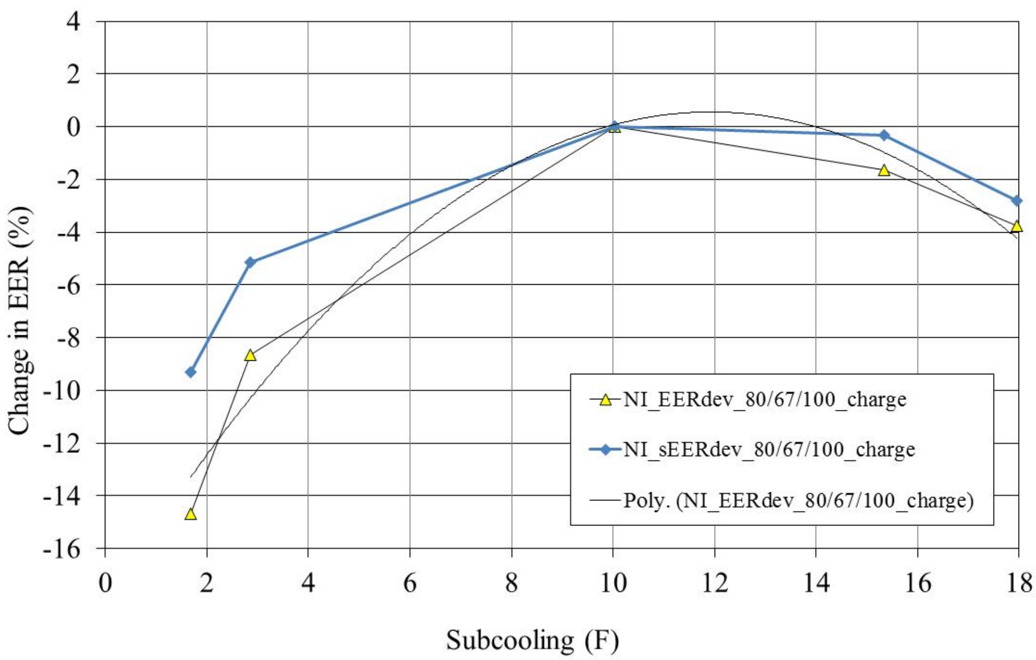

Figure 2. Change in EER and Subcooling with Refrigerant Charge – Experimental Data, Ni, TxV System

4. Glossary

Parameter	Description	English Units	SI Units
AC	Air Conditioner		
CT	Refrigerant Condensing Temperature based on saturation temperature for LP	F	C
EERdev	EER deviation (change) from the nominal condition		
ET	Refrigerant Evaporating Temperature based on saturation temperature for SP	F	C
ICFM	Indoor (evaporator) Airflow	ft^3/min (cfm)	L/s
ITD	Indoor air Temperature Difference	F	C

Parameter	Description	English Units	SI Units
	(RDB-SDB), corresponds to gross capacity (does not include fan heat)		
LP	Refrigerant Liquid Pressure	psia	kPa
OAT	Outdoor Air dry-bulb Temperature	F	C
OCFM	Outdoor (condenser) Airflow	ft^3/min (cfm)	L/s
RDB	Return (indoor) air Dry-bulb Temperature	F	C
RWB	Return (indoor) air Wet-bulb Temperature (entering evaporator)	F	C
SC	Refrigerant Subcooling (condenser exit)	F	C
SDB	Supply air Dry-bulb Temperature (leaving evaporator, does not include fan heat)	F	C
sEERdev	Sensible EER deviation (change) from the nominal condition		
SH	Refrigerant Superheat (compressor suction)	F	C
SHR	Sensible Heat Ratio	none	
SP	Refrigerant Suction Pressure	psia	kPA
TS	Temperature Split, dry-bulb temperature difference from return plenum to supply plenum (RDB-ADB), includes the effect of fan heat $TS \approx ITD - 1.1°F$	F	C
TxV	Thermal expansion valve		
80/67/95	Test (or simulation) condition designation – example RDB/RWB/OAT	F	C
PA_SH_80/67/95_Charge	Laboratory (experimental) data Charge parametric study		

5. References

5.1. Kim, M. Payne, W.V. and Domanski, P.A. 2006. Performance of a Residential Heat Pump Operating in Cooling Mode with Single Faults Imposed. Report NISTIR-7350, NIST, September 2006. [NIST 2006; NI data]

5.2. Shen B., Groll E. A., Braun J. E., 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 1173-RP, ASHRAE. [Shen 2006; PA data]

5.3. Temple, K. 2008. Expanded Test Protocols for Low Ambient Testing of Unitary AC Systems. BERG Project Final Report. Grant 54921 A/06-09B. September 2008. [Temple 2008]