EXECUTIVE SUMMARY
FINAL REPORT ARTI-21CR/605-50015-01

EVALUATION AND MODELING OF SPLIT-SYSTEM AIR CONDITIONER PERFORMANCE AT EXTREME AMBIENT TEMPERATURES WITH R-410A OPERATING UP TO THE CRITICAL POINT

ABSTRACT

The air conditioning performance of R-410A, an HFC replacement for R-22, is reduced at higher-temperature ambient conditions relative to R-22. The primary purpose of this project was to improve and validate air conditioning equipment performance modeling using R-410A at elevated ambient temperatures up to the critical point. Our work complemented the equipment testing in a parallel ARTI project with equipment performance analysis, relevant modeling improvements, and with system performance comparisons to the Oak Ridge National Laboratory (ORNL) Heat Pump Design Model (HPDM). We found that the compressor performance of the tested systems at elevated ambient temperatures is degraded relative to the manufacturer's data under standard test conditions. Mainly because of this, an uncorrected model under-predicts R-410A performance drop-off at higher ambient temperatures. Comparing R-410A to R-22 at 125ºF ambient, we found 11% larger drop in energy efficiency rating (EER) and 5% in capacity, with a 6% larger increase in power. When these effects were accounted for in the model, there was good agreement in performance trends with ambient temperature. The ORNL HPDM, using calibration factors that varied linearly with ambient, was able to simulate the performance of the R-410A system up to within 1ºF of the critical temperature. Refrigerant subcooling was found to be maintained fairly constant with thermostatic expansion valve (TXV) control, dropping slowly at higher ambient temperatures.

The system performance at elevated ambient temperatures of variable vs. fixed opening refrigerant flow controls is also evaluated. TXV control has less drop-off in EER and capacity at higher ambient temperatures than with fixed-flow controls, especially compared to capillary tube control. This is primarily due to the smaller drop in subcooling with ambient. However, power draw with a TXV is higher than for fixed-flow controls because higher condenser pressures are maintained at elevated ambient temperatures.

Recommendations are made regarding research needed to better characterize the effects of reduced compressor shell cooling on compressor performance. Refrigerant line heat loss modeling was also identified as a need for better prediction of absolute performance at more extreme ambient temperatures. Improvements are also needed in capillary tube modeling for R-410A, as the ASHRAE generalized correlation for capillary tubes was found to have transport property related errors in its development.