DR13.06: Variable-Capacity Space Conditioning Systems for Residential

RESIDENTIAL EFFICIENCY AND PERFORMANCE

In recent years, variable capacity (VC) technology has been implemented into common U.S. configurations of heating, ventilation, and air conditioning (HVAC) equipment. VC refers to the ability to modulate a system's cooling or heating output in response to the actual loads of the conditioned space. An HVAC system typically achieves VC by incorporating a variable speed (VS) compressor and indoor blower into the design, as well as a control system to allow for intelligent modulation of the unit's cooling or heating output in response to thermal loads and user input. In residential space conditioning, VC technology has been incorporated into central or ducted split HVAC equipment. In general, residential VC systems offer the highest rated efficiency of a given manufacturer's product offering.

Understanding the performance of residential VC systems is key for utilities that aim to utilize these systems as energy efficiency or demand response (DR) resources. To this end, this study investigated a range of residential VC air conditioners (ACs) for California's climate and applications by conducting a technical survey of available equipment, a laboratory assessment under realistic operating conditions, and a field study which recorded VC equipment operation over an entire cooling season. The study also included a lab and field demand response (DR) assessment on the selected VC systems.

The results of this research study demonstrate the efficiency and performance of residential VC air conditioners of varying design and SEER. The laboratory findings may be utilized to determine a VC system's equipment efficiency for a given California application. The field results demonstrate three different applications with residential VC equipment and provide an investigation of the equipment performance and of system effects at the selected sites.

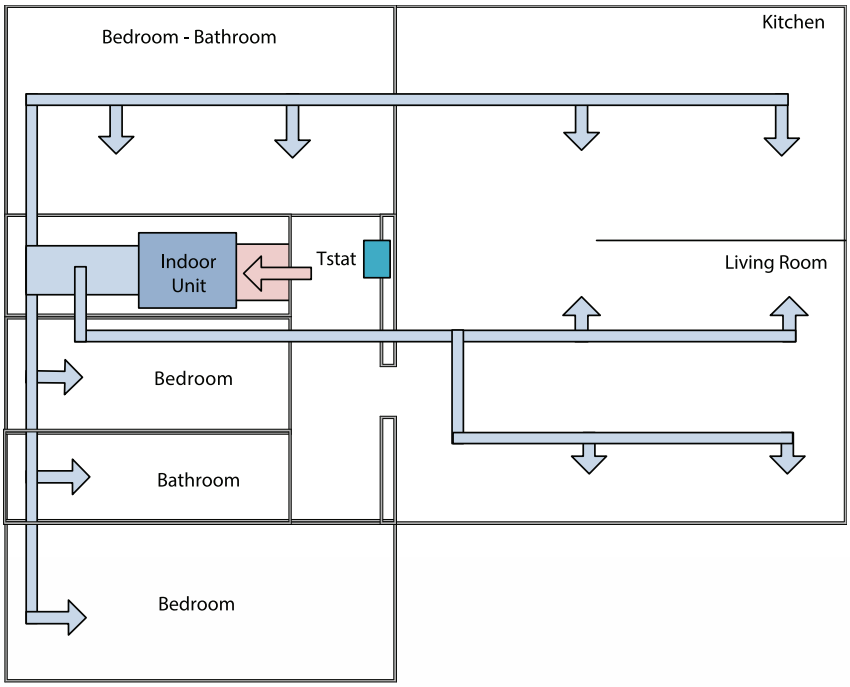

Figure 1: Home Layout and Ductwork

INTRODUCTION

What Is This Technology?

EQUIPMENT MODULATES CAPACITY TO MEET ACTUAL CONDITIONS

Variable capacity refers to the ability of a space conditioning system to modulate cooling or heating output in response to the thermal loads of the conditioned space and user input of the occupants. VC equipment typically offers highest or near the highest rated efficiency for any HVAC configuration. VC systems are produced for residential ducted split equipment by the majority of leading U.S. HVAC manufacturers. This study explored the performance and efficiency of multiple VC systems applicable for the California residential market.

What We Did

THREE 2-TON DUCTED VARIABLE CAPACITY A/C SYSTEMS

Lab and field testing was performed for three 2-ton high-static ducted VC-A/C systems with varying SEER efficiency ratings. The focus was on the system response to demand control signals under different operating conditions.

Lab testing was conducted according to a modified psychometric method based on the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) 210/240 rating method for unitary air conditioners and heat pumps. However, the laboratory tests examined a more extensive range of conditions than that required by the 210/240 standard. The team developed a laboratory performance map for each system to assist in the efficiency evaluation of VC products and documented each unit's DR functionality to demonstrate its DR capabilities.

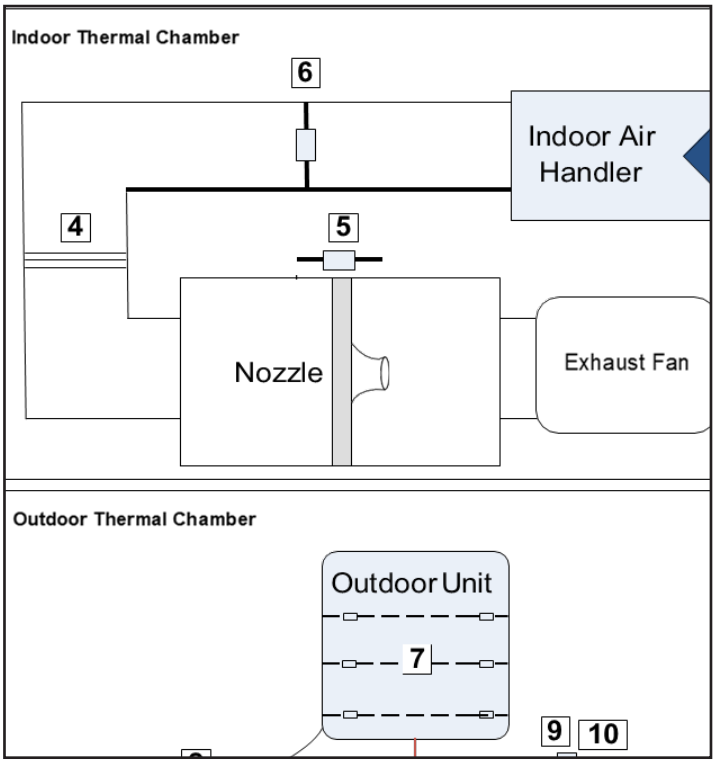

Figure 1: Example laboratory performance map to assist in the efficiency evaluation of VC products

Field test monitoring of the VC equipment over the cooling season measured the following:

- Power, voltage, current, and power factor
- Temperature and humidity at multiple locations such as unit return and supply
- Refrigerant line temperature to ensure valid operation of the VC equipment

FINDINGS

POTENTIAL HVAC EFFICIENCY GAINS: The VC-to-baseline comparisons demonstrated increasing energy savings with increasing SEER, as well as a potential efficiency enhancement for utility programs. In the field, the project team determined an expected seasonal cooling efficiency for each field site on the basis of the laboratory data for each of the three selected VC systems and each field site's operational characteristics. For the appropriately sized units, the expected seasonal cooling efficiency compared well to the measured seasonal cooling efficiency based on field data. Based on utility billing data and field monitoring data, the VC equipment and quality installation retrofit resulted in cooling season energy savings of approximately 30%, 18%, and 30% for the 20, 17.5, and 21 SEER equipment, respectively.

IMPLICATIONS FOR DEMAND RESPONSE: The project team examined DR unit setup and DR operation of selected VC equipment in laboratory and field evaluations. DR operation consisted of OFF-cycle controls. VC system 2 claimed to have OFF-cycle and low stage capacity modulation controls. To enable DR operation, the VC equipment in this investigation required manual adjustments of dry-contacts in the outdoor units. VC systems 2 and 3 also required further adjustment of controls/thermostat settings in combination with dry-contact adjustment to enable DR operation. None of the equipment investigated was readily able to receive and act upon utility DR event signals. Additional research and potential software updates will be needed in the future relating to demand response capabilities with residential VC systems.

LAB vs FIELD: Comparing AHRI ratings for the units involved in the study vs. the lab and field data that was gathered, it appears that the AHRI data compared reasonably well with the study results. The field design conditions resulted in a reduction in capacity and efficiency of approximately 9%-15% vs. AHRI test conditions while maintaining similar unit power consumption.

RESEARCH AND EDUCATION IS VITAL: For continued investigation of residential VC space conditioning and utility programs in California, multiple areas of research could be considered: the prevalence and mitigation of oversizing of HVAC equipment; duct loss impact with variable airflow equipment; and further demonstration of field energy savings of VC equipment.

MARKET AVAILABILITY: The survey confirmed the market availability of high SEER (17 to 24 SEER) VC equipment in air conditioner or heat pump configurations and the typical range of residential and small commercial sizes. Available VC equipment includes fully variable speed equipment and five-speed systems. In addition, VC systems are available with DR capabilities that allow the systems to cycle OFF or potential operate at a minimum level of cooling output.

CONCLUSIONS

What We Concluded

RESIDENTIAL VC-UNITS OFFER STRONG ENERGY SAVINGS POTENTIAL BUT ADDITIONAL RESEARCH IS NEEDED

This study demonstrated the potential efficiency and DR capabilities of the VC equipment for California residences and utility programs through a survey, laboratory testing, and field testing.

The laboratory evaluation focused on VC air conditioners of 18, 19.5, and 22 SEER. All three systems demonstrated improved efficiency at part-load operation for a specific indoor and outdoor condition. Modeling for the California Climate Zone 10 demonstrated the following:

- Compared a baseline 14 SEER air conditioner, 18, 19.5, and 22 SEER VC equipment can provide energy savings of 12%, 26%, and 30%, respectively.
- Compared to the current utility program level of 15 SEER, 18, 19.5, and 22 SEER VC equipment can provide energy savings of 7%, 22%, and 26%, respectively.

In this research study, the potential energy savings of VC equipment over baseline 10 to 12 SEER equipment was demonstrated to be higher in the laboratory (30%–50%) than in the field (18%–30%). The discrepancy in potential energy savings between the lab and field may be attributed to system effects, such as differences in duct loads between fixed-speed and variable speed equipment, or to the use of utility billing data to determine the baseline HVAC energy usage. Utility billing provides a readily available tool for exploring energy savings, but it does not directly provide valuable data on HVAC unit power consumption, indoor temperature and humidity, or unit operating air or refrigerant conditions. Such information would enable a more thorough comparison of HVAC energy usage at a residence.[i]

These Findings are based on the report, “Residential VC Space Conditioning – Buildings III: Sub-Project A” which is available from the ETCC website at www.etcc-ca.com/reports

Footnotes

[i]Residential VC Space Conditioning – Buildings III: Sub-Project A. Emerging Products (SCE), September 2016.