U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Building America Case Study
Efficient Solutions for New and Existing Homes

Impacts of Improved Duct Insulation on Fixed-Capacity (SEER 13) and Variable-Capacity (SEER 22) Heat Pumps

Cocoa, Florida

PROJECT INFORMATION

Project Name: Draft Report: Cooling and Heating Seasonal Energy and Peak Demand Impacts of Improved Duct Insulation on Fixed-Capacity (SEER 13) and Variable-Capacity (SEER 22) Heat Pumps

Location: Cocoa, FL

Partners:
Building America Partnership for Improved Residential Construction
www.ba-pirc.org

Building Component: HVAC

Application: New and/or retrofit; single and/or multi-family

Years Tested: 2010–2014

Applicable Climate Zone(s): IECC climate zones 1-4

PERFORMANCE DATA

Net Cost of Energy-Efficiency Measure (SEER 21/22 vs. SEER 13): $3,500

Projected Energy Savings: 2,800 kWh/y

Projected Energy Cost Savings: $324/y

Net Cost of Energy-Efficiency Measure (R12 vs. R6 attic ducts): $530

Projected Energy Savings: 242 kWh/y

Projected Energy Cost Savings: $28/y

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A new generation of central, ducted, variable-capacity heat pump systems has come on the market, promising very high cooling and heating efficiency. Rather than cycling on at full capacity and then cycling off when the thermostat is satisfied, cooling and heating outputs vary over a wide range (approximately 40% to 118% of nominal full capacity); thus, staying "on" for 60% to 100% more hours per day compared to fixed-capacity systems. It should be noted that two-stage systems were not evaluated in this research effort.

Although the variable-capacity system uses less total energy than the fixed-capacity system, the longer runtime of the variable-capacity system accounts for a greater energy increase percentage when going from an indoor to attic duct system. Preliminary research (comparing fixed-capacity and variable-capacity, three-ton heat pumps) identified that switching from an indoor duct system to an attic duct system caused a 13% increase in cooling energy use for the fixed-capacity system versus 21% for the variable-capacity system.

Further experiments examined the performance of two-ton and three-ton fixed- and variable-capacity systems and the impacts of system oversizing. Monitored energy consumption over 24 months at a highly instrumented lab house (Figure 1, page 2) found that oversizing a SEER 22 variable-capacity system yielded 8% cooling energy savings and 1.5% heating energy savings. Figure 3 (page 2) shows the variable capacity efficiency versus the cooling capacity delivered as a percentage of total available capacity. Figure 3 also shows higher efficiencies when the system operates at its lower capacities, and it also indicates that increases in cooling load result in a relative decreases in efficiency.

Current Phase 4 experiments show duct R-value enhancements benefit the overall operating efficiency of the variable-capacity system compared to the fixed-capacity system. The effective R-value of the attic duct system was increased from 6.1 to 11.6 by applying a foil-faced fiberglass insulation product (Figure 2, page 2). The relative energy performance of the fixed- and variable-capacity systems was examined with this higher efficiency attic duct system.

Figure 1. AHUs for SEER 13 (top) and SEER 22 (bottom) 2-ton heat pumps can be connected to indoor or attic ducts.

Figure 2. Duct section after insulation wrap has been installed. In the red rectangle, the foil facing will be tucked under and cellulose added. In the red circle, the foil facing is tucked under, and a small amount of cellulose insulation was added where the duct wrap meets the existing cellulose.

*Oversizing generally reduced both seasonal and peak energy consumption for the variable-capacity systems. For the fixed-capacity systems, oversizing generally increased both seasonal and peak cooling and heating energy consumption.

For more Information, refer to the Phase I Report: *https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/64695.pdf*.

Image credit: All images were created by the BA-PIRC Team.

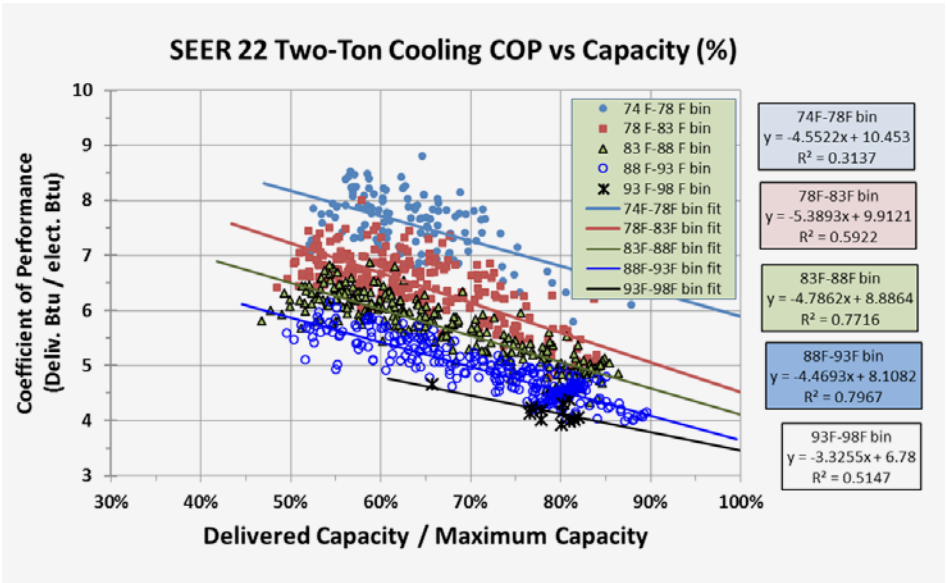

Figure 3. Measured cooling COP versus capacity fraction for a variable-capacity 2-ton SEER 22 system for various outdoor temperature bins.

At a daily average of 82°F outside and 77°F inside, cooling energy savings from the duct insulation upgrade was 6.4% for the fixed-capacity SEER 13 system, 6.9% for the variable-capacity SEER 22 system (in standard control mode), and 8.2% for the variable-capacity SEER 22 system (in relative humidity (RH) control mode).

Lessons Learned

- If ducts cannot be moved indoors, energy can be saved by adding insulation to ducts in attic spaces; however, the labor cost would likely result in long payback periods greater than 15 years.
- Peak cooling demand savings from the duct insulation upgrade showed peak demand reductions of 2.9%, 15.3%, and 11.7% for the SEER 13, SEER 21, and SEER 22 system configurations, respectively, at 92°F outdoors and 77°F indoors. Peak cooling demand savings for the SEER 13 fixed-capacity system were understated because the two-ton fixed-capacity heat pump was unable to meet the full cooling load during a portion of peak hours at design conditions during the pre-retrofit period.
- Oversizing* a variable capacity system by about twice the design cooling load resulted in increased energy savings and acceptable indoor relative humidity.

Looking Ahead

A study of various sized dual-capacity heat pumps would help establish guidance on optimal sizing as well as energy impacts from going from indoor ducts to attic ducts.

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