JPUR
JOURNAL OF PURDUE UNDERGRADUATE RESEARCH

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Performance Testing of a Unitary Split-System Variable-Speed Heat Pump

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Heating, ventilation, and cooling (HVAC) systems amount to 55% of residential energy consumption in the United States, according to the 2010 edition of Moncef Krarti's *Energy Audit of Building Systems: An Engineering Approach*. Heat pumps are energy efficient alternatives to traditional HVAC systems. Conventional heat pumps function with an on/off controller; the compressor and fans of the system are single speed, meaning they can only operate at full capacity. This results in frequent on/off cycles, increasing the fatigue on system components and causing significant fluctuations in the indoor temperature. Variable speed compressors and fans increase the efficiency of heat pumps by smoothly adjusting heating and cooling capacity to meet a building's conditioning requirements. In addition to increased efficiency, variable-speed heat pumps are well suited to participate in demand response (DR) programs. This research aims to verify the improvement in efficiency and the DR capabilities of a variable-speed heat pump.

The Seasonal Energy Efficiency Ratio (SEER) (i.e., cooling efficiency) and the Heating Seasonal Performance Factor (HSPF) (i.e., the heating efficiency) quantify the performance of a heat pump. The American National Standards Institute/Air-Conditioning, Heating, and Refrigeration Institute (ANSI/AHRI) Standard 210/240, from the "2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment," provides the testing matrices for determining the SEER and HSPF for both a single- and variable-speed heat pump. Since the heat pump is variable speed, it has the capability to operate in both single- and variable-speed mode. These required tests are performed in psychometric chambers at the Ray W. Herrick Laboratories. The resulting single and variable speed SEER and HSPF ratings are summarized in Table 1.

Single Speed		Variable Speed		Improvement	
SEER	HSPF	SEER	HSPF	SEER	HSPF
14.05	8.7	20	10	35%	14%

Table 1. Single and variable speed SEER and HSPF comparison.

DR programs allow a power company to avoid rolling blackouts and large-scale power outages by turning off participants' HVAC systems in exchange for financial compensation. While the single-speed heat pumps of participating residences are turned off during such events, variable-speed heat pumps have a DR mode, which initiates minimum-speed operation. The testing for DR mode is performed by running the heat pump at full speed, initiating DR, and returning to full-speed operation. To quantify the instantaneous performance of the heat pump during DR mode, the coefficient of performance (COP) is calculated. The COP is defined as the cooling/heating provided by the heat pump divided by the electrical energy required. The COP during the DR test is shown in Table 2.

Full Speed COP	Minimum Speed COP
5	7

Table 2. COP during the DR test.

Performance testing of the variable-speed heat pump confirms the increase in efficiency and DR capabilities. The SEER and HSPF showed significant improvement over traditional single-speed heat pumps (as shown in Table 1). The DR mode functions as expected and demonstrates an increase in performance during minimum-speed operation. Variable-speed heat pumps offer increased efficiency, increased temperature control, lower equipment fatigue from frequent on/off cycles, and perform effectively during DR events.

Research advisor Eckhard Groll writes: "Air-source heat pumps utilizing variable-speed compressors and fans offer significant efficiency improvements over traditional single-speed systems. This is achieved by reducing system cycling and the corresponding inefficiencies. Yet, the majority of the residential heat pumps in the United States are still single-speed systems. More research is needed to make variable-speed systems viable alternatives."

Variable speed heat pump in the psychrometric test chamber.

Son, F. J. (2017). Performance testing of a unitary split-system variable-speed heat pump. *Journal of Purdue Undergraduate Research*, *7*, 83–84. https://doi.org/10.5703/1288284316413