Thermal Performance Evaluation of a Small Duct High Velocity System Using NIST's Net- Zero Energy Residential Test Facility

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DISCLAIMERS

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SUMMARY

This study aims to evaluate the performance of a Small Duct High Velocity (SDHV) heat pump relative to a Conventionally-Ducted Heat Pump (CDHP) using one-year of detailed data from the two-story Net-Zero Energy Residential Test Facility (NZERTF) on the campus of the National Institute of Standards and Technology (NIST). The NZERTF is a single-family home that serves as a laboratory with simulated occupancy and scheduled internal loads. During the analysis period, the SDHV and the CDHP were alternately operated every other week in order to compare the two systems under similar weather conditions. The preliminary analysis indicated that the SDHV system might not always provide thermal comfort comparable with the CDHP. Potential reasons are lower supply airflow rates from the SDHV during the heating season in this low-load house, and a tight thermostat deadband range for the CDHP, which resulted in comparatively more frequent on-cycles.

KEYWORDS

Measurement and Verification; Thermal comfort; IEQ; Low-energy building technology

1 INTRODUCTION

Small Duct High Velocity (SDHV) systems have been recognized as a potential retrofit solution for older residential or historic buildings that were not originally designed for central air distribution systems because of their space savings and easier modular installation, requiring less demolition. Another potential benefit is improved thermal comfort due to enhanced dehumidification and air mixing. However, few studies (Baskin and Vineyard, 2003; Poerschke, 2017) have measured and verified SDHV system thermal performance in residential buildings. The existing studies are also based on short-term measurements or focused solely on SDHV performance verification rather than a performance comparison between SDHV and conventionally-ducted systems using the same test house. Therefore, this study evaluated the performance of a SDHV heat pump by comparing it with a Conventionally-Ducted Heat Pump (CDHP) using one-year of detailed building and system data collected from the NIST's Net-Zero Energy Residential Test Facility (NZERTF).

2 METHODS

This study collected one-year of high resolution (i.e., 10-sec or 1-min) data throughout the NZERTF in Gaithersburg, MD from September 2016 to August 2017 along with coincident outdoor weather data. The NZERTF provides a unique platform for comprehensive, accurate measurements to explore various designs, technologies, and control strategies to achieve net-zero energy performance (Fanney et al., 2015). The NZERTF is a single-family home that serves as a laboratory with simulated occupancy and scheduled internal loads. During the analysis period, the SDHV and the CDHP were operated alternately every other week in order to compare the two systems under similar weather conditions. This analysis closely followed the methods outlined in the ASHRAE PMP (2010) and Kim and Haberl (2014).

3 RESULTS AND DISCUSSION

The preliminary analysis of the data revealed that on average, both the SDHV and CDHP systems reasonably maintained the house close to the thermostat set-point temperatures (i.e., 21.1°C in the heating season and 23.9°C in the cooling season). The CDHP system maintained room temperatures in a tighter range than the SDHV system during the cooling season, which was mainly due to a smaller thermostat deadband for the CDHP, i.e., ±0.1°C. This result was more obvious for the rooms on the first floor where the thermostat was located. It was also found that there were several occasions when measured humidity levels exceeded the upper humidity limit recommended in the ASHRAE Standard 55 (2013) during the cooling season, which was more noticeable when the SDHV system was on standby (scheduled to run but inactive).

When floor- and room-level data were examined, the SDHV system maintained smaller temperature differences during the cooling season. The average floor-to-floor and room-to-room temperature differences in the SDHV operation mode was 1.0°C during the cooling season, which was about half of the temperature differences measured when the CDHP was operating. This meant that the bedrooms on the second floor were consistently warmer than the set-point temperature during the cooling season, which indicates the potential for discomfort in the warm range on the second floor in the CDHP operation mode.

The vertical and horizontal temperature stratification within a single room was also analyzed using the data collected from a 3 x 3 x 3 grid measurement system in a second floor bedroom. The measured vertical temperature stratification in this bedroom was 0.54°C on average in the SDHV operation mode during the heating season, which was higher than the measured vertical temperature stratification when the CDHP was operating (i.e., 0.20°C). Because the SDHV system has a variable stage compressor and variable speed fan, it delivers lower supply airflow rates in this low-load house during the heating season. An unintentional consequence of lower supply airflow rates was slightly poorer air mixing than with the CDHP's intermittent but higher supply airflow rates.

4 CONCLUSIONS

Preliminary analysis indicated that the SDHV system at the NZERTF might not always provide thermal comfort comparable with a CDHP system. Potential reasons are lower air supply airflow rates from the SDHV during the heating season in this low-load house, and a tight thermostat deadband for the CDHP. Additional analyses are planned to confirm the findings.

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