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Renewable Energy Systems and Sustainability Conference 2017

Lakeland, FL

August 1, 2017
Bringing Housing Innovations to Market

www.buildingamerica.gov
Introduction

- Tighter construction = less natural ventilation.
  - Whole-house mech. vent. more important
- Better insulation and windows decreases cooling.
- Results in more difficulty managing moisture.
- Potential Issues- comfort, building damage, health
Introduction

• Variable Capacity (VC) heat pumps vary output of heat/cool.
  – Variable outdoor compressor speed and refrigerant
  – Variable indoor fan flow
  – Quiet
  – Long runtime
  – Energy efficient
Ductless Mini-split Heat Pump Shown with a Dehumidifier
Effective Moisture Control Requires a Balance Between Wetting and Drying Processes

About 9.6 – 10.6 gallons (36.3-40.1 liters) of water needs to be removed from air each summer day.

External
(Summer)
Mech. Vent. (48 pints)
Infiltration (17 pints)

Internal
12-20 pints/day
cooking
bathing
people
House Lab and Residential Field Study
Warmer Weather Results in More Moisture Removed From Indoors

![Graph showing the relationship between outdoor temperature and condensate production, with equations for standard and drycool conditions.]

Condensate vs Out Temperature

- **Drycool pounds water**: $y = 0.0488x^2 - 3.7899x + 70.424$
  $R^2 = 0.906$
- **Standard cool pounds water**: $y = 4.5518x - 291.01$
  $R^2 = 0.8644$
Colder Supply Temperature Results in Lower Indoor RH

\[ y = 1.1036x - 7.5898 \]

\[ R^2 = 0.7694 \]
Thermal Control

Thermal distribution was acceptable from all tested VC systems. $dT>3^\circ F$ Only 1.4% of time for 11 bedrooms in 4 homes (prefer indoor about 76F).

Average hourly temperature difference between SEV1 bedrooms and the main body
House Lab Space Conditioning Energy

![Graph showing the energy consumption of different cooling and heating systems.](image)

**Fixed Capacity SEER13 Ducted**

**VC SEER22 Ducted**

**VC Ductless Mini-split SEER 21.5**
# Potential Daily Cooling Energy Savings from Fixed Capacity to Variable Capacity

*(Central Ducted Systems)*

<table>
<thead>
<tr>
<th>Lab Test Configuration</th>
<th>SEER 13 FC kWh/day</th>
<th>SEER 14 VC kWh/day (%0)</th>
<th>SEER 22 VC kWh/day (%0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OA Near Central Return; Dehumidifier Enabled @ 60% RH</td>
<td>24.4</td>
<td>22.4</td>
<td>19.2</td>
</tr>
<tr>
<td>Savings Relative to SEER 13</td>
<td>---</td>
<td>2.0 (8.2%)</td>
<td>5.2 (21.3%)</td>
</tr>
<tr>
<td>Savings Relative to SEER 14</td>
<td>---</td>
<td>---</td>
<td>3.2 (14.3%)</td>
</tr>
</tbody>
</table>

*Daily Space Conditioning Energy for a Typical Summer Day with $dT = 5^\circ F$*
## Predicted Annual Cooling Energy, Peak Cooling Power, Use and Savings
(Savings Relative to Ducted FC SEER 13)

<table>
<thead>
<tr>
<th>Test Case</th>
<th>Annual kWh (Mbtu)</th>
<th>Annual Savings kWh/yr (Mbtu), %</th>
<th>Peak kW (kBtu/h)</th>
<th>Peak Reduction kW (kBtu/h), %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Ducted Fixed Cap. SEER 13; DH</td>
<td>4820 (16.45)</td>
<td>---</td>
<td>2.04 (6.97)</td>
<td>---</td>
</tr>
<tr>
<td>2 Ducted Variable Cap. SEER 22; DH</td>
<td>3743 (12.77)</td>
<td>1078 (3.68) <strong>22.4%</strong></td>
<td>1.56 (5.33)</td>
<td><strong>0.48</strong> (1.64) <strong>23.5%</strong></td>
</tr>
<tr>
<td>3 Ductless MSHP SEER 21.5; no DH</td>
<td>3224 (1.10)</td>
<td>1596 (5.45) <strong>33.1%</strong></td>
<td>1.49 (5.09)</td>
<td><strong>0.55</strong> (1.88) <strong>27.0%</strong></td>
</tr>
</tbody>
</table>
House Lab RH Control

Standard Cool Indoor RH

Dry Cool Indoor RH

Standard Cool Indoor RH & AC Runtime

Dry Cool Indoor RH & AC Runtime
Field Study RH Control

- High frequency in hourly average RH >60%.
  - Assoc. with overnight and seasonal low-load periods
  - -with elevated supply air temp. (high SHR during low-load)

- RH maintained low enough to avoid high potential for health or durability issues.
- No reported comfort complaints from occupants.

![Average hourly RH and monthly average temperature in SS2](image)
Conclusion

- Field studies indicate VC not controlling RH <70% well-enough during low-load periods in mech. vent. homes. RH >70% control OK.
- Lab study of SDHV VC system shows VC can manage RH well and may be able to maintain all hours below 50% RH with improved DRY cool mode.
- VC provided good thermal distribution.
- VC cooling savings range from 8% to 33% compared to Fixed Cap (VC SEER 14 lowest and VC MSHP SEER 21.5 ductless highest).
Conclusion

Variability of indoor RH levels primarily from variability of:

• Mechanical Ventilation Rates
• Internal Moisture Generation
• Cooling SHR of Air Conditioning
Summary

VC Great Potential and Needs Improved

- Need improved algorithms & control architecture to improve Dry modes.
  - Need to maintain colder coil during low load and decrease SHR.
  - Need to utilize lowest capacity over longer periods during low load.
Summary
VC Great Potential and Needs Improved

- Cooling should prioritize efficiency over RH control in STANDARD mode.
- Prioritize RH control over efficiency in DRY mode.
- Use RH sensor to intelligently move back into high efficiency when RH low enough.
Thank You

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