Advanced HVAC Humidity Control Strategies for Hot-Humid Climates

Coordinate for Air Quality, Comfort, and Energy Efficiency

Cooling

RH control

Ventilation

Home Innovation Research Laboratories
Vladimir Kochkin, Division Director, Applied Engineering and Building Science
vkochkin@homeinnovation.com
# Project Summary

## Timeline:
- **Start date:** September 2017
- **Planned end date:** September 2020

## Key Milestones
1. Enrolment of test homes – Spring 2018
2. Initial field results – Fall 2018 / Spring 2019

## Budget:

### Total Project $ to Date:
- **DOE:** $298,500
- **Cost Share:** $78,100 ($35,000 monetary; $43,100 in-kind)

### Total Project $:
- **DOE:** $622,134
- **Cost Share:** $161,300 ($70,000 monetary, $91,300 in-kind)

## Key Partners:
- **Goodman Manufacturing**
- **Aprilaire®**
- **K. Hovnanian**
- **David Weekley Homes**
- **Wrightsoft®**
- **ACCA**
- **NAHB**
- **AB Systems**
- **NREL**

## Project Outcome:
1. Defined metrics for enhanced dehumidification mode for central AC systems
2. An HVAC control strategy that coordinates and optimizes the operation of the AC and the ventilation systems
3. HVAC design and integration solutions for builders in hot humid climates
<table>
<thead>
<tr>
<th>Team</th>
<th>Dave Mallay</th>
<th>Nay Shah</th>
<th>Vladimir Kochkin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Research Engineer</td>
<td>Research Engineer</td>
<td>Project Oversight</td>
</tr>
</tbody>
</table>

| | Gary Ehrlich | Ryan Kennett | Jim Hoffner | Derek Holtman |
| | NAHB         | Goodman Mfg. | K. Hovnanian | Mike Funk     |
| |             |              | Homes       |               |

| | Armin Rudd | Scott Grefsheim | Glenn Hourahan, P.E. | Bill Wright |
| | AB Systems | Aprilaire® | ACCA | Wrightsoft® |

Image of the team members with their roles and company affiliations.
**Challenge**

**Problem Definition:**

1. For new homes equipped with whole-house mechanical ventilation, managing indoor humidity in hot-humid climates is one of the top issues for builders of all sizes and types.
2. AC systems are rated and designed to COOL and dehumidification will take care of itself.
3. Builders are often reluctant to install supplemental dehumidifiers because of cost, durability, maintenance, integration with the rest of the HVAC, occupant operation, other factors.
4. Ventilation can create comfort issues.
5. Energy efficient homes may be more prone to higher RH levels if humidity control is not addressed.

![Example latent loads as a percentage of total loads](image)

**Fragmented Value Chain:**

1. Risk transfer – who is responsible?
2. Communication barriers – who is the decision maker?
4. Quality control: design and installation.

---

**Builder**  
**HVAC Designer**  
**OEM**  
**Ventilator Provider**  
**Control Providers**  
**T-stat Provider**  
**HVAC Trades**
Challenge

- Very Recent Moisture Issues in Hot-Humid Markets
Approach

- Develop and validate a coordinated humidity and ventilation control strategy for central ducted systems that improves comfort and energy performance in hot-humid climates:
  - Identify metrics for enhanced AC dehumidification mode
  - Develop a control protocol for coordinating ventilation operation with AC operation
  - Identify limitations of the strategy and offer solutions for add-on supplemental dehumidification
  - Conduct modeling (partner – NREL)

- Metrics for optimization and coordination:
  - Indoor humidity at or below 60% RH
  - Part-time load conditions
  - Energy consumption (AC, ventilation, distribution)
  - Functionality (distribution; comfort; control)
  - Cost to install and operate
Enhanced Dehumidification

- **Goal = reduce the sensible heat ratio (SHR) when additional humidity control is needed**
  - Use advanced controls with a standard central heat pump or furnace/AC
    - Variable-speed ECM drive (not multi-speed)
    - Thermal Expansion Valve (TXV)
  - Operate at **full** compressor capacity
  - Establish the min air flow for the equipment to operate without freezing the evaporator (indoor) coil or damaging the system
  - Mode selection based on interior RH level either at onset or during the AC cycle
  - Thermostat, dead-band selected to maximize humidity control with minimal over-cooling
  - Optimize ramping profile during cooling to improve humidity control and minimize re-humidification at end of cycle
Prioritized Ventilation

- Outdoor air is ducted into return plenum at the air handler (supply type ventilation)
  - Outside air is conditioned during on-cycle and is always filtered and distributed
- Dedicated ventilation fan, ASHRAE 62.2-2010 capable
- Maximize ventilation **time and rate** during on-cycles
  - Double the continuous rate during on-cycle
  - Ventilate during off-cycles at reduced rate and only when a 4-hour target has not been met
- Maximum ventilation rate at 10% of HVAC system air flow
- Use “Smart Ventilation” during mild/favorable weather
- Relying on the air handler fan for distribution
  - Circulation (off-cycle) mode at 25% of normal AC air flow
Approach

- Prioritized Ventilation – Example Savannah GA

- During heating season on-cycle ventilation provides 95% of 62.2-2010 rate
- During cooling season on-cycle ventilation provides 80% of 62.2-2010 rate
- Over 12 months, combined on-cycle ventilation at twice continuous rate and off-cycle ventilation at half rate meet 62.2-2010
Impact

- Facilitate Builder Transition to High-Performance Homes
- Evaluate the limitations of and the potential for relying on a central HVAC system for maintaining humidity and comfort in energy efficient homes
- Allow builders to rely on the existing infrastructure for HVAC design and installation – simplify the transition while improving performance – finding the “sweet spot”
- Develop metrics for standardizing enhanced dehumidification mode across OEMs
- Develop metrics for control protocols for coordination of equipment operation: AC, furnace, ventilator, zones, thermostat
Progress

- Worked with Goodman to develop an enhanced dehumidification protocol/controls, Winter 2018
- Developed a ventilation protocol with Aprilaire, Summer 2018
- Conducted test house design reviews of ACCA Manual J/S/D with Wrightsoft and HVAC partners, Spring 2018
- Commissioned and instrumented systems at 3 test homes: Houston 1-stage & 2-stage AC, Savannah 1-stage HP (Fall 2018)
Progress

Sample Measured Refrigerant Performance Characteristics in Dehumidification Mode

- Measured at 70% of system airflow (245 CFM/ton – 30% reduction from 350 CFM/ton or 37% of typical 400 CFM/ton)
- Goodman’s Design Engineer and Regional Technical Manager measured and determined acceptable performance
- Calculated sensible heat ratio (SHR) at measured conditions was 62% (0.62) representing a significant increase in latent capacity compared to typical SHR of 80% in normal AC mode
- A 60% airflow was evaluated and deemed too marginal for consistent reliable operation
Enhanced Dehumidification: Sample Field Data

- Ramping profile maximizes latent performance for normal AC mode
- Dehumidification mode kicks in when indoor humidity exceeded a specified trigger (e.g., 55%)
- Next design iteration will update the ramping profile for dehumidification mode
Prioritized Ventilation and Indoor Conditions: Sample Field Data

- Ventilation during on-cycle: air handler operates at normal airflow
- Ventilation during off-cycle: air handler operates at 25% of normal airflow
- RH is maintained at below 53% during this window
Stakeholder Engagement

- “Baked” into the project from the beginning
- Key to success of the overall effort
- Stakeholders contributing cash, time, expertise, products
- The project was kicked off with two face-to-face meetings between the OEM (Goodman) and builder representatives
- Engaged during design, installation, commissioning
- Initial results have been reviewed with Goodman and builders
- Stakeholders will help with application and dissemination of results
Remaining Project Work

- Continue monitoring of three instrumented homes
- Enroll two additional test homes using an updated system design
- Engage with ACCA and AHRI on increasing transparency of the latent capacity of the equipment
- Finalize a set of standardized metrics for enhanced dehumidification mode
- Finalize control protocols for coordination of equipment operation: AC, furnace, ventilation, zones, thermostat, and supplemental dehumidification
- Develop resources for builders to facilitate decision making process on selecting a humidity control strategy
Thank You

Home Innovation Research Labs
Vladimir Kochkin, Division Director
vkochkin@homeinnovation.com
301-430-6249
REFERENCE SLIDES
Project Budget

Project Budget: See Table below  
Variances: None  
Cost to Date: See Table below  
Additional Funding: None

<table>
<thead>
<tr>
<th>FY 2017 – FY 2018 (past)</th>
<th>FY 2019 (current)</th>
<th>FY 2020 (planned)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DOE</strong></td>
<td><strong>Cost-share</strong></td>
<td><strong>DOE</strong></td>
</tr>
<tr>
<td>$227,074</td>
<td>$68,870</td>
<td>$213,572</td>
</tr>
</tbody>
</table>
## Project Plan and Schedule

### Project Schedule

<table>
<thead>
<tr>
<th>Project Start: 09-15-2017</th>
<th>Completed Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projected End: 09-14-2020</td>
<td>Active Task (in progress work)</td>
</tr>
</tbody>
</table>

- **Milestone/Deliverable (Originally Planned)**
- **Milestone/Deliverable (Actual)**

<table>
<thead>
<tr>
<th>FY17</th>
<th>FY2018</th>
<th>FY2019</th>
<th>FY2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q4 (Jul-Sep)</td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
</tr>
<tr>
<td>Q4 (Jul-Sep)</td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
</tr>
<tr>
<td>Q4 (Jul-Sep)</td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
</tr>
<tr>
<td>Q4 (Jul-Sep)</td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
</tr>
<tr>
<td>Q4 (Jul-Sep)</td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
</tr>
<tr>
<td>Q4 (Jul-Sep)</td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
</tr>
</tbody>
</table>

### Advanced HVAC Humidity Control for Hot-Humid Climates

#### Past Work

- **2.0 Establish the Project Team**
- **3.0 Establish the Research Plan**
- **4.1 Modeling Analysis**
- **4.2 Develop Prototype HVAC Design**
- **5.1 Install and Instrument Prototype System**
- **5.2 Develop Updated Design**
- **5.3 Enroll test houses for Updated HVAC Design**
- **6.0 Develop Draft Latent Efficiency Rating Protocol**
- **GO/NO-GO Decision Point**

#### Current/Future Work

- **7.0 Interim Results Update**
- **8.0 Install and Instrument the Updated HVAC Design**
- **9.0 Evaluate Results**
- **10.0 Develop Best Practices and Design Guidance**