Humidity Control Strategies

Armin Rudd

Residential Building Energy Efficiency Meeting 2010
20 July 2010; 2:40 pm
Humidity control goals

- Comfort, and Indoor Air Quality
  - Control indoor humidity year-around, just like we do temperature

- Durability and customer satisfaction
  - Reduce builder risk and warranty/service costs
Humidity control challenges

1. In humid cooling climates, there will always be times of the year when there is little sensible cooling load to create thermostat demand but humidity remains high
   • Cooling systems that modify fan speed and temperature set point based on humidity can help but are still limited in how much they can over-cool

2. More energy efficient homes have less sensible heat gain to drive thermostat demand but latent gain remains mostly the same
   • Low heat gain windows
   • Ducts in conditioned space
   • More, and better-installed, insulation
   • Less heat gain from appliances and lighting
3. More energy efficient cooling equipment often has a higher evaporator coil temperature yielding less moisture removal
   • Larger evaporator coil by manufacturer design, or up-sized air handler unit or air flow by installer choice
4. Conventional over-sizing to cover for lack of confidence in building enclosure or conditioning system performance causes short-cycling yielding less moisture removal
System engineering trade-offs

- Start with high-performance building enclosure
  - Improves the more permanent features of a home which has longer-term sustainability benefits
    - Low loss/gain glass, controlled air change, ducts inside conditioned space, pressure balancing
  - Allows for reduced cooling system size
    - Helps pay for the enclosure improvements
    - More compact duct system lowers cost and helps get the ducts inside
  - Makes overall building performance more predictable
    - Gives confidence for right-sizing equipment
      - No short-cycling: Better moisture removal, Higher average efficiency, Better spatial mixing
    - Controlled ventilation instead of random infiltration
  - Results in decreased energy consumption along with increased occupant comfort
Outdoor Conditions

Houston

Austin

Dallas

Jacksonville

Orlando

Okla. City
Dewpoint Temperature (F)

- Interior
- Phoenix
- Seattle
- Fargo
- Tampa

Interior threshold

<table>
<thead>
<tr>
<th>Season</th>
<th>Tdb</th>
<th>RH</th>
<th>Tdp</th>
</tr>
</thead>
<tbody>
<tr>
<td>winter</td>
<td>72</td>
<td>35</td>
<td>43</td>
</tr>
<tr>
<td>spring</td>
<td>75</td>
<td>45</td>
<td>52</td>
</tr>
<tr>
<td>summer</td>
<td>77</td>
<td>50</td>
<td>57</td>
</tr>
<tr>
<td>fall</td>
<td>75</td>
<td>45</td>
<td>52</td>
</tr>
</tbody>
</table>
Moisture load for cooling and dehumidification systems in humid climates (75 F/55% RH indoor, 75 F outdoor dewpt)

Moisture Load (lb water/day)

Source for Cooking through New construction drying: Natural Resources Canada
Cooling Load for:
50 cfm OA, Tdb,in=75, Tdp,in=55, Tdp,out=75

Outdoor air temperature (F)

Cooling load (W)

Cooling load (Btu/h)
## Systems Tested – Houston, TX

<table>
<thead>
<tr>
<th>System Type</th>
<th>Location</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAND-ALONE IN CLOSET</td>
<td>19803 Ash., 19902 Ash.</td>
<td>2 story, 2386 ft², 2397 ft²</td>
</tr>
<tr>
<td>STAND-ALONE IN ATTIC</td>
<td>19950 Ash., 2731 Sun.</td>
<td>2 story, 2397 ft², 2448 ft²</td>
</tr>
<tr>
<td>ULTRA-AIRE</td>
<td>19915 Ash., 19938 Ash., 19923 Ash.</td>
<td>1 story, 2100 ft², 2 story, 2448 ft², 2 story, 2397 ft²</td>
</tr>
<tr>
<td>FILTER-VENT + STAND-ALONE</td>
<td>19934 Ash., 19922 Ash., 19954 Ash.</td>
<td>1 story, 1830 ft², 1 story, 2100 ft², 2 story, 2386 ft²</td>
</tr>
<tr>
<td>ERV</td>
<td>19926 Ash., 19942 Ash., 19930 Ash.</td>
<td>1 story, 1830 ft², 1 story, 2197 ft², 2 story, 2448 ft²</td>
</tr>
<tr>
<td>2-STAGE + ECM AHU</td>
<td>19422 Col.</td>
<td>1 story, 2197 ft²</td>
</tr>
<tr>
<td>ENERGY EFFICIENT REFERENCE</td>
<td>2802 Sun., 2814 Sun., 19906 Ash.</td>
<td>2 story, 2386 ft², 1 story, 2197 ft², 2 story, 2386 ft²</td>
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<tr>
<td>STANDARD REFERENCE</td>
<td>19622 Her., 4818 Cot., 6263 Clear.</td>
<td>2 story, 2448 ft², 1 story, 2197 ft², 2 story, 3300 ft²</td>
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</tbody>
</table>
Dehumidifier and ventilation duct in interior mechanical closet with louvered door
Dehumidifier process

Dehumidifiers add heat to the space
Ducted dehumidifier in conditioned space with living space control
Pulling the data together

- **Data set**
  - 43 homes, each with one to four T/RH space measurements
  - Data recorded hourly for a year or more
  - 27 homes also had equipment runtime measurements (cool, heat, fan, dehumidifier)
Houston (29), Austin (3), Dallas (3), Jacksonville (2), Ft. Myers (2), Orlando (1), Oklahoma City (3)

All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dillingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands
Observations and Conclusions for Higher-Performance houses

- All Higher-Performance houses with ventilation showed a marked increase in space humidity compared to Standard and Medium houses with ventilation.
- The combination of Higher-Performance low sensible heat gain buildings and mechanical ventilation significantly increases the number of hours that require dehumidification without sensible cooling.
  - Higher cooling balance point temperature than for conventional Standard houses
  - High space humidity occurs mostly during spring and fall swing seasons, rainy periods, and summer nights
- The effect of reducing the latent ventilation load through energy recovery was insufficient to avoid high humidity at part-load and no-load conditions.
- Humidity loads in Higher-Performance homes cannot consistently be met by conventional or enhanced cooling systems. Supplemental dehumidification is needed.
Moral of the story:

The addition of supplemental dehumidification to Higher-Performance homes in warm-humid climates enables continued improvements in energy efficiency while ensuring against elevated indoor humidity.
But what about making the existing cooling or heat pump equipment also do the supplemental dehumidification?

Goals:

- Provide year-around relative humidity control in high-performance (low-sensible gain) houses
- Without over-cooling the space
- At lower installed cost than the same efficiency heating and cooling system with an additional high efficiency dehumidifier
- By making standard DX cooling equipment switchable between normal cooling and dehumidification-only using condenser reheat
Central system with modulating hot gas reheat

Evaporator coil

Modulating hot gas reheat coil

Fan

Supply Air

Return Air

Entering Air

Dew Point

Leaving Air

Supply Air

W1

W2

T1

T2

Modulate the hot gas reheat to a target supply air temperature
Modulating hot gas reheat valve

- DIGITAL STEPPER VALVE
- STEPPER MOTOR WITH 3193 STEPS
- NOT AN OPEN/CLOSE VALVE

![Graph showing voltage and time relationship](image)

HOT GAS REHEAT VALVE
### Efficiency

#### Matching CB and F1, Air Conditioner Performance

<table>
<thead>
<tr>
<th>Condensing Unit</th>
<th>Air Handler</th>
<th>Nominal Capacity</th>
<th>SEER/EER</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB-024</td>
<td>F1-024</td>
<td>24 MBH / 2 Tons</td>
<td>Up to 17.30 SEER/</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Up to 13.80 EER</td>
</tr>
<tr>
<td>CB-036</td>
<td>F1-036</td>
<td>36 MBH / 3 Tons</td>
<td></td>
</tr>
<tr>
<td>CB-048</td>
<td>F1-048</td>
<td>48 MBH / 4 Tons</td>
<td></td>
</tr>
<tr>
<td>CB-060</td>
<td>F1-060</td>
<td>60 MBH / 5 Tons</td>
<td></td>
</tr>
</tbody>
</table>

#### Matching CB and F1, Heat Pump Performance

<table>
<thead>
<tr>
<th>Condensing Unit</th>
<th>Air Handler</th>
<th>Nominal Capacity</th>
<th>SEER/EER</th>
<th>HSPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB-024</td>
<td>F1-024</td>
<td>24 MBH / 2 Tons</td>
<td>Up to 15.80 SEER/</td>
<td>Up to 9.70</td>
</tr>
<tr>
<td>CB-036</td>
<td>F1-036</td>
<td>36 MBH / 3 Tons</td>
<td>Up to 13.05 EER</td>
<td></td>
</tr>
<tr>
<td>CB-048</td>
<td>F1-048</td>
<td>48 MBH / 4 Tons</td>
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<td></td>
</tr>
</tbody>
</table>
PSYCHROMETRIC CHART
Normal Temperature
SI Units
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa

Chart by: HANDS DOWN SOFTWARE, www.handsonsoftware.com
Efficiency AMPLIFIED by tracking an optimal condensing temperature

Copeland Scroll UltraTech®

ECM® Condenser Fans

Copeland Data Condensing Temperature

Condensing Temperature Points

Isentropic Efficiency

Watts

Residential Building
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Digital Scroll

Copeland Scroll Digital™

Compressor Capacity Modulation

- Power (watts)
- Capacity (BTU)

Graph showing the relationship between compressor capacity modulation and power consumption.
AAON Heat Pump with modulating condenser reheat testing

- RA temp
- RA rh
- SA temp
- Total W-h/min

Dehumidifier mode

Minutes

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Monitoring Data
Heat pump with modulating condenser reheat

Air side T and RH

- Tsup
- Tret
- RHsup
- RHret
- Tstat
- RHstat
- W-h/min

Gaps, Barriers, and Future Work

- Smaller capacity equipment with adequate and efficient air distribution
- Further cost reduction of dehumidifying equipment through design and manufacturing optimization
- Better understanding of moisture load factors due to occupant behavior
- Better understanding of humidity control impacts of sensible heat gain reduction in mixed-humid climates
- More laboratory and field testing of cooling and dehumidifying equipment to establish better performance maps for simulation models
- New rating standard for cooling and dehumidifying equipment to aid in proper humidity control design and equipment selection