Promoting quality installation of central AC (and heat pump) systems

Energy Design Conference and Expo
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Topics for today

- What do we know about the incidence and impacts of QI issues in the Midwest?
- What is the current landscape of utility programs addressing QI issues?
- What do we most need to learn to make programs better?
Central AC systems are not plug-and-play

- Size
- Refrigerant charge
- Airflow
- Controls
- Duct leakage
Sizing
What’s out there (in WI)?

- 2 tons: 40%
- 2.5 tons: 24%
- 3 tons: 23%
- 3.5+ tons: 7%
- 1.5 tons: 6%
- 3.5+ tons: 7%

Source: ECW Residential Characterization Study (1999)
Aggregate Manual-J estimated contribution to design cooling load for 37 homes in Madison, WI
What’s often missing from Manual J calculations?

- Shading
- Lo-e windows
- Hidden insulation
- Thermostat setpoint
- Air leakage
After-the-fact Manual J Calculations for 37 WI homes

<table>
<thead>
<tr>
<th>Undersized by...</th>
<th>1 ½ ton</th>
<th>1</th>
<th>3%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 ton</td>
<td>3</td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>½ ton</td>
<td>9</td>
<td>24%</td>
</tr>
<tr>
<td>Appropriately sized</td>
<td></td>
<td>13</td>
<td>35%</td>
</tr>
<tr>
<td>Oversized by...</td>
<td>½ ton</td>
<td>10</td>
<td>27%</td>
</tr>
<tr>
<td></td>
<td>1 ton</td>
<td>1</td>
<td>3%</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

86% within ½ ton
What do run-time data say about sizing?
Relative size (based on monitored operation)

250% oversized
200% oversized
150% oversized
100% oversized
50% oversized
Appropriately sized
50% undersized

39 sites, sorted from lowest to highest
Cycling for some systems looks like this...

\[\begin{array}{c}
\text{On} \\
\text{Off} \\
\text{On}
\end{array}\]

...and like this for others

\[\begin{array}{c}
\text{Off} \\
\text{On} \\
\text{Off}
\end{array}\]
Sizing Experiment

- Load calcs said: 1.5 tons needed
- New 3-ton unit installed in 2005
- New 2-ton unit installed in 2006
  - (same make/model)
- Monitoring over both summers
No difference in energy consumption!

- 3-ton: $518 \pm 56$ kWh
- 2-ton: $522 \pm 43$ kWh
Sizing bottom line (from WI research)

- Most systems are over-sized
  - Think twice before installing anything over 2.5 tons
  - Many homes would be fine with 1.5 tons
- But it’s difficult to size accurately
- Proper sizing will…
  - …not likely save much energy (unless you’re WAY off)
  - …save some money on installed cost
  - …help avoid indoor hurricanes (if airflow is reduced)
  - …perhaps provide better humidity control
Expansion Device
(Fixed or Thermostatic)
Refrigerant Charge Field Test
~10% significantly undercharged
~10% overcharged
~50% somewhat undercharged
~30% OK

Charge error (%)

Efficiency relative to correct charge (%)

Fixed orifice expansion device
- older units

Thermostatic expansion valve (TXV)
- newer units

undercharged
overcharged
AIRFLOW
Three types of blower motors

- **PSC** (permanent magnet split capacitor)
  - Low cost, lower efficiency, limited airflow range, doesn’t maintain airflow

- **ECM** (electronically commutated motor)
  - Higher cost, higher efficiency, large airflow range, maintains airflow

- **Constant Torque (aka “X13”)**
  - Not as expensive as ECM
  - ECM efficiency
  - Capable of large airflow range, but limited selection (set by OEM)
  - Maintains airflow better than PSC

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ECM vs. PSC airflow

Tested airflow range (cfm)

Typically ~525 Watts per 1,000 cfm
Typically ~325 Watts per 1,000 cfm

Measured airflow range for some individual PSC air handlers

typical cooling mode airflow range for an ECM air handler
Airflow

Cfm per ton

PSC
ECM

Little air conditioner w/ big furnace

Big air conditioner w/ little furnace

70 sites, sorted from lowest to highest
Measured EER impact of changing airflow

- ECM air handler
- PSC air handler

% change in EER vs. Change in airflow (cfm per ton)

Improved efficiency
Reduced efficiency
Airflow bottom line

- Check airflow
  - Especially if small AC w/ large furnace
- Reduce airflow if possible (to a degree)
- Install an ECM furnace (or maybe X13)
## Tuning – overall results

<table>
<thead>
<tr>
<th>Type of adjustment</th>
<th>Older systems (n=21)</th>
<th>New SEER 10-13 systems (n=10)</th>
<th>New SEER 14+ systems (n=30)</th>
<th>All systems (n=61)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airflow</td>
<td>6 (28%)</td>
<td>0 (0%)</td>
<td>14 (47%)</td>
<td>24 (39%)</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>15 (71%)</td>
<td>7 (70%)</td>
<td>11 (37%)</td>
<td>33 (54%)</td>
</tr>
<tr>
<td>Coil clean</td>
<td>8 (38%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>8 (13%)</td>
</tr>
<tr>
<td>Filter replacement</td>
<td>1 (5%)</td>
<td>0 (0%)</td>
<td>3 (10%)</td>
<td>4 (7%)</td>
</tr>
<tr>
<td><strong>Mean % EER improvement</strong></td>
<td><strong>3.1 ± 6.1%</strong></td>
<td><strong>13.3 ± 20.9%</strong></td>
<td><strong>4.6 ± 3.9%</strong></td>
<td><strong>5.4 ± 4.1%</strong></td>
</tr>
<tr>
<td>Site</td>
<td>System Description</td>
<td>% EER improvement</td>
<td>Adjustments</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>--------------------</td>
<td>-------------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>3-ton, non-TXV, non-ECM, R-22, SEER 10</td>
<td>68%</td>
<td>Corrected 88% undercharge.</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>2-ton, non-TXV, non-ECM, R-22, SEER 13</td>
<td>55%</td>
<td>Corrected 58% undercharge.</td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>1.5-ton, non-TXV, non-ECM, R-22, SEER 10</td>
<td>31%</td>
<td>Corrected 33% undercharge. Reduced airflow 131 cfm for 245 watt reduction in air handler power. Cleaned condenser coil.</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>2.5-ton, non-TXV, ECM, R-22, SEER 10</td>
<td>27%</td>
<td>Cleaned condenser. Corrected 27% undercharge. Small airflow adjustment had negligible impact.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>2-ton, TXV, non-ECM, R410a, SEER 14</td>
<td>26%</td>
<td>Reduced airflow 320 cfm for 210 watt reduction in air handler power.</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>2.5-ton, non-TXV, non-ECM, R-22, SEER 10</td>
<td>25%</td>
<td>Corrected 18% undercharge.</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>3-ton, non-TXV, non-ECM, R-22, SEER 14</td>
<td>25%</td>
<td>Corrected 37% undercharge.</td>
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<tr>
<td>34</td>
<td>2-ton, TXV, ECM, R410a, SEER 14</td>
<td>18%</td>
<td>Reduced airflow 195 cfm, for 240 watt reduction in air handler power. Correction of 4% overcharge also improved EER slightly.</td>
<td></td>
</tr>
</tbody>
</table>
Two important controls

- **Airflow setting for Fan-on operation**
  - ECM FAR superior—if set correctly!

- **Cooling-mode fan-off delay**
  - Don’t use in humid climates!
How much water is in a “houseful” of summer indoor air?

- **75°F, 50% RH:** 1½ gallons
- **75°F, 67% RH:** add ½ gallon

How much water is stored on a 2-ton coil when it is fully saturated?

- About ¼ to ½ gallon
Better humidity control associated with

- Hours of AC operation
  - Better (smaller) sizing
    - = more hours of AC operation
    - = fewer hours of uncontrolled humidity

- Home tightness
  - Tighter keeps the outdoors out

- Auto-Fan operation (not constant fan)
Condensing Gas furnaces

- Orifice size and gas manifold pressure
  - Affects firing rate
- Airflow and temperature rise
- Controls
Minnesota QI/QM programs

- **Existing unit tune-up**
  - Typically $25 incentive
  - Must be licensed contractor, but not necessarily registered with utility

- **QI for new standard-efficiency unit**
  - Typically $50 incentive
  - Typically must be registered installer

- **QI for new high-efficiency unit**
  - Higher incentives, depending on SEER/HSPF
  - Typically must be registered installer

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Minnesota QI/QM programs, cont.

<table>
<thead>
<tr>
<th>Company</th>
<th>Existing system tune-up</th>
<th>Offer QI for Std. eff. system?</th>
<th>Require QI for high-eff system?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xcel</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Great River Co-ops</td>
<td>Some</td>
<td>Some</td>
<td>Yes</td>
</tr>
<tr>
<td>MN Power</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Interstate</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Ottertail</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Municipals</td>
<td>Some</td>
<td>Some</td>
<td>Some</td>
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<tr>
<td>Utility</td>
<td>Number of Registered Contractors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great River</td>
<td>1,142</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xcel</td>
<td>750</td>
<td></td>
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<tr>
<td>Minnesota Power</td>
<td>154</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Other notable QI programs

- CheckMe® (Proctor Engineering Group)
- CoolSaver (CLEAResult)
- HVAC SAVE (MEAA)
Current research in MN (CARD project)

- Market research
  - Interviews with distributors, contractors, utilities and others
  - Homeowner survey
- Field research
  - Field tests on 120 systems
  - Run-time monitoring of 60 systems
- Synthesis
  - What does this tell us?
    - Two facilitated meetings of interested stakeholders

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Programs should emphasize installation practices that...

...have a high incidence of issues

...offer good savings from getting it right

...contractors are willing and able to implement
What do YOU think is important to learn from this research?
Thank you!

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