Experiences Embedding FDD into Residential and Light Commercial Products

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Agenda

- Market Survey of FDD
- Answer why a gap exists between products and literature
- Case study illustrating the challenges commercializing a new diagnostic feature
- Recommendations
Fault Detection

- Vapor Compression Cycle
  - High pressure cutout (Safety requirement)
  - Low pressure cutout (Warranty benefit)
  - Coil Freeze stats
  - Discharge thermostat

- Fans
  - Blower proving switch

- Gas furnaces
  - Sophisticated controls driven by safety requirements
  - Most inputs digital

- Generate numerous fault codes.
  - Commercial – over 150 error codes
  - Residential – over 100 error codes

- Error codes typically do not point directly to root cause.
Virtual Sensors

- Indoor Airflow
  - Airflow measurement using BLDC (ECM) motors
    - Motor drive knows speed and power
    - Apply to fan curves to calculate airflow
  - Residential
    - Many units have constant airflow control
    - Dirty filter detection, duct static
    - Error codes associated with excessive fan power
- Commercial applications <5tons
- **Compressor** –
  - Sense compressor current and control signals
  - Aimed at reducing the number of misdiagnosed compressor failures

- **Refrigerant Charge**
  - Subcooling based charging tool
  - Only used during charging

- **Expansion Device**
  - Diagnostics embedded with EEV control
  - Sensor failure
  - Stuck valve
  - High superheat
Economizer FDD Features

- California Title 24 Requirements (Jan 2014)
  - Air temperature sensor fault
  - Not economizing when it should
  - Economizing when it should not
  - Damper not modulating
  - Excess outdoor air

- Several offerings announced
  - Many more to follow
Summary of FDD in Embedded Systems

- Complete vapor compression cycle diagnostics
- Continuous Refrigerant Charge Diagnostics
- CA Title 24 Regulation
- Increasing Volume
- Incremental Cost
#1 Challenge: Business Case

Customer Benefits
- Dealer Installer Service
- Owner Occupant Energy MGR

Product Cost
- Component Cost
- Development Cost
  - Engineering time
  - Lab Facilities

Many Projects Competing for Limited Resources
Example: Economizer Diagnostics

- **Features**
  - Air temperature sensor fault
  - Not economizing when it should
  - Economizing when it should not
  - Damper not modulating
  - Excess outdoor air

- **Customer Benefits**
  - Reduced commissioning time
  - Energy savings
    - Reduced over ventilation
    - Maximize economizer use
  - Improved IAQ
    - Prevent under ventilation
Challenges Quantifying Energy Savings

- Savings vary based on the following
  - Climate
  - Equipment sizing / building type
  - Probability of a failure
    - Part failure
    - Commissioning error
    - Data makes someone look bad

- Requires Statistical Analysis
  - Use Monte Carlo analysis
  - Results difficult to understand

- Difficult to relate IAQ to energy
  - Under ventilation saves energy
Example: Ventilation Error when not calibrating

<table>
<thead>
<tr>
<th>Actual Ventilation Rate (CFM)</th>
<th>Desired Ventilation Rate (CFM)</th>
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<tbody>
<tr>
<td></td>
<td>DESIGN A</td>
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<td></td>
<td>DESIGN B</td>
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Ventilation ERROR when Using Percent Open = Percent OD air

- Average Error +86 CFM
- Average Error -71
Additional Commercialization Challenges

- **Integration into sales tools**
  - Simple simulation to calculate annual energy consumption
  - Tools assume perfectly running units
  - Can’t subtract savings from annual energy consumption

- **Typically sold using anecdotes**
  - Unit in Chicago, economizer fails open in June costing $$

- **Field service desires consistent feature set**
  - Want all units to have same FDD
  - Impractical to roll out features on all units at once.
Steps to Improve Commercialization

- Generate confidence in FDD
  - Ratings or evaluation process as good as SEER
  - SPC 207 is a good start

- Relate FDD to energy savings
  - Good: Industry accepted procedure
    - What is the probability of a fault occurring
    - What is the probability of detection with and without FDD
    - Need simple tools
  - Ideal: Refrigerant charge diagnostics = +1 SEER

- Associate FDD with installation savings
  - Reduced inspections if FDD enabled
  - Studies verifying reduced call backs
Thank you

Any Questions?

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