New Buildings Institute
Advances in HVAC Technology: Fault Detection and Diagnostics

National Conference on Building Commissioning
April 2006

New Buildings Institute
White Salmon, WA
www.newbuildings.org & www.advancedbuildings.net

Formed in December 1997 as a not-for-profit public benefits corporation
Working with partners in: California, Northwest, Northeast & Midwest
Funding:
- Sponsors
- Grants
- Contracts
Changing markets through research, guidelines, codes, and training
Developed Advanced Buildings™ and Advanced Lighting Guide

New Buildings Institute Projects
- Advanced Automated HVAC Fault Detection and Diagnostics Commercialization Program
- Hot/Dry Air Conditioner Project
- Indirect Evaporative Cooler Monitoring Project
- Evaporative Cooler Market Assessment
- University of CA-CIEE Campus Project
- Building Performance Review
- Advanced Buildings / ALG Revision
- Getting to Fifty: www.advancedbuildings.net
- PNW and NEEP RTU-DTU Programs
FDD: So Who’s and What’s at Fault?

- 2/3’s HVAC systems large & small
- Everyone’s holding on tightly

FDD or Controls?

- It’s the controls, stupid...
- FDD is a natural control functionality
- Provides persistence & reliability of:
  - energy/demand savings
  - performance
  - efficiency
- Technology and training

Advanced, Automated HVAC Fault Detection and Diagnostics (FDD) Commercialization Program

DEVELOP & DEMONSTRATE:
- Advanced Fault Detection and Diagnostics Methods and Measurement Equipment for HVAC Systems Both Rooftop and Built Up
- More Advanced and More Fault Resistant HVAC Equipment
PIER FDD: Market Connections

- Identify/assess/implement activities/mechanisms to move successful FDD products into markets
- Influence codes/standards/regulators in California and nationally
- Strategic Partnerships

FDD Project 2: Web-Enabled Diagnostics System

Project Lead: Architectural Energy Corporation

- Based on NIST AHU Performance Assessment Rules-APAR
- Dual duct AHU/chiller systems
- Chiller/cooling tower diagnostics
- Customer data transmission to web-based diagnostic engine with UI
- Tridium first development partner
- Ongoing commissioning functionality

Current User Interface: Site tab

- Define and select sites and buildings
Current User Interface: Equipment

Define AHUs

Map required points to history archives

Current User Interface: Configure

Activate rules and FDD processing

Set fault detection parameters

FDD Project 2: Field Test Status

- Alpha testing (Colorado)
  Western Building Services has provided access to buildings in Denver area
  - Denver Athletic Club
    Multiple air handlers; district CHW and steam
  - Regis University (library)
    Large dual duct
  Currently, air handler rules are being evaluated; chiller and cooling tower data is not yet available
- Beta testing (California)
  Building has not yet been identified
FDD Project 2: Requirements for CA Test Site

- Required HVAC equipment:
  - Central plant equipment:
    - Chiller
    - Cooling tower
    - One or more air handlers
- Currently installed Niagara system (AX or R2) is highly desired
- Site suggestions are requested immediately

FDD Project 3: AHU-VAV Diagnostics

Project Lead: National Institute of Standards and Technology (NIST)

- AHU Performance Assessment Rules + VAV box control charts
- Very low cost; embedded in controller logic
- BACnet enabled; works through existing BAS
- 28 AHU faults, 7 VAV box faults; rule-based trend logging
- Current development partners: Alerton, Automated Logic Corporation, Delta Controls, Tour Andover Controls
- Case Study of 450 Golden Gate Bldg: 2 AHUs + 1000 VAV
- Ongoing commissioning functionality
- Algorithms in public domain
- www.archenergy.com/pier-fdd/

FDD Algorithms Field Sites

<table>
<thead>
<tr>
<th>Site descriptor</th>
<th>Location</th>
<th>Manufacturer</th>
<th>AHUs</th>
<th>VAVs</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALC corporate headquarters building</td>
<td>Atlanta, GA</td>
<td>ALC</td>
<td>2</td>
<td>53</td>
</tr>
<tr>
<td>Philip Burton Federal Building</td>
<td>San Francisco, CA</td>
<td>Norton</td>
<td>2</td>
<td>1000</td>
</tr>
<tr>
<td>Marten corporate headquarters building</td>
<td>Redmond, WA</td>
<td>Norton</td>
<td>1</td>
<td>47</td>
</tr>
<tr>
<td>NIST campus</td>
<td>Gaithersburg, MD</td>
<td>Alerton + Andover</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Foley Federal Building</td>
<td>Las Vegas, NV</td>
<td>Delta</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Montgomery College Health Sciences Building</td>
<td>Takoma Park, MD</td>
<td>Norton</td>
<td>2</td>
<td>181</td>
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<tr>
<td>Pennsylvania Military Museum</td>
<td>Bensalem, PA</td>
<td>ALC</td>
<td>2</td>
<td>0</td>
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<tr>
<td>Shippenburg University</td>
<td>Shippenburg, PA</td>
<td>ALC</td>
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<td>29</td>
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<tr>
<td>Iowa Energy Center BDS</td>
<td>Ankeny, IA</td>
<td>Invensys</td>
<td>0</td>
<td>11</td>
</tr>
</tbody>
</table>

* in the works
FDD Algorithms - What's Next?

- AHU: dual duct, multi-zone
- Unit ventilators, fan coil units, zone reheat, zone dampers, unit/cabinet heaters
- A/C, heat pumps, evap coolers
- Chillers and boilers
- Cooling towers

FDD Project 4: Advanced Rooftop Unit

- Project Lead: Architectural Energy Corporation
- 5-ton rooftop unit prototype
- More robust operation
- Economizer enhancements
- FDD capabilities
- POC unit test about to begin

RTU Market

- In terms of number of systems installed, the most popular packaged DX system size is 5 tons, representing 24% of total units sold.
- Units up to 10 tons represent close to 90% of the total unit sales in new commercial buildings in California.
- 155 million square feet of new commercial building construction in CA each year
- Approximately 39 million square feet (25%) use packaged air conditioning units of 10 tons or less in capacity.
FDD Project 4: ARTU

- Economizer improvements
- Fan improvements
- Unit efficiency
- Refrigeration cycle improvements
- Fan controls
- Refrigerant control

- Thermostat capability
- Sensors
- Installation & checkout capability
- Advanced monitoring
- Embedded diagnostics

FDD Project 5: Rooftop Unit Diagnostics Project

Lead: Field Diagnostic Services, Inc.

- Automated data acquisition
- Wireless communications to website/email
- 25 alarm conditions; 5-50 tons; 1-2 stage
- Safety, energy, occupant comfort prioritized
- Trend log data graphed
- Utility costs/ROR on repair
- Ongoing commissioning functionality
Embedded Diagnostics Alarms

**Refrigeration Cycle**
- poor condenser heat transfer
- poor evaporator heat transfer
- refrigerant flow restriction
- low refrigerant charge
- high refrigerant charge
- low compressor pumping efficiency
- non-condensable gas in system
- sensor problem

**Air Handler**
- no economizer cooling at low OAT
- high outdoor air fraction when high OAT
- low outdoor air fraction when occupied
- DCV signal and low OSA fraction
- low mixed air temperature
- low airside temp difference during heat or cool
- high airside temp difference during heat or cool
- sensor problem

**Controls**
- continuous call for cooling or heating
- simultaneous heating and cooling
- fan cycling, not continuous during occupied period
- fan running continuous when unoccupied
- mechanical cooling at low OAT-no economizer
- t-stat cooling/heating demand, but no cooling/heating
- compressor short cycling sensor problem
- extended run time
- sensor problem
Embedded Diagnostic UI

Unit Status

Company: GSRC
Site: GSRC Atlanta
Unit: RTU-1
Expansion Device: TxV
Stg 1 Capacity: 15 tons
Model:
Number of Stages: 2
Refrigerant: R22
Stg 2 Capacity: 15 tons
Make: Trane
SEER: 10

Embedded Diagnostic UI

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<tbody>
<tr>
<td>RTU-1</td>
<td>OK</td>
<td>OK</td>
<td>1 alarm</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>RTU-2</td>
<td>OK</td>
<td>OK</td>
<td>1 alarm</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>RTU-3</td>
<td>OK</td>
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<td>1 alarm</td>
<td>OK</td>
<td>OK</td>
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<td>1 alarm</td>
<td>OK</td>
<td>OK</td>
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<td>OK</td>
<td>OK</td>
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</tr>
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</table>

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PIER PAC Mtg. May 22, 2002
Embedded Diagnostic UI

**Alarm Category**
- Equipment Safety Alarm: 2 Alarms
- Energy Savings Opportunity: 1 Alarm
- Comfort Alarm: OK
- Monitoring System Alarm: OK

**Alarm Details**
- **Description:** Evaporating temperature is lower than expected
- **Fault Condition:** Steady-state cooling operation and evaporating temperature less than 28°F
- **Occurrence Condition:** 10 minutes accumulated during a day
- **Possible Cause:** Low indoor airflow, refrigerant flow restriction
- **Possible Impact:** Frozen indoor coil, energy use
- **Alarm Trigger Date:** Jan 29, 2006
- **Alarm Last Observed Date:** Feb 03, 2006

**Alarm History**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Alarm</th>
<th>Trigger Date</th>
<th>Event Date</th>
<th>Event Time</th>
<th>Username</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTU-1</td>
<td>No Economizer Cooling at Low OAT</td>
<td>Dec 02, 2004</td>
<td>No Records Found</td>
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<td></td>
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<tr>
<td>RTU-1</td>
<td>Low Evaporating Temperature</td>
<td>Dec 05, 2004</td>
<td>No Records Found</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>RTU-1</td>
<td>Short Compressor Off Time</td>
<td>Oct 21, 2005</td>
<td>No Records Found</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## New Buildings Institute

### Embedded Diagnostic UI

#### Cooling Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Last Cooling Date</td>
<td>Nov 20, 2005</td>
</tr>
<tr>
<td>Mechanical Cooling Efficiency In</td>
<td>No Steady State Data Avai</td>
</tr>
<tr>
<td>Mechanical Cooling Runtime Frac</td>
<td>0.188</td>
</tr>
<tr>
<td>Economizer Cooling Runtime Frac</td>
<td>0</td>
</tr>
<tr>
<td>Cooling Cycles</td>
<td>N/A</td>
</tr>
<tr>
<td>Occupied Period Outdoor Air Frac</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### Embedded Diagnostics-Results

- 5 buildings, 15 RTUs (HP/package), 5-15 tons
- monitored 4-10 months
- 60% with short compressor on cycles (<5")
  - reduced equipment life, part load perform
- 80% with short compressor off cycles (<5")
  - reduced equipment life

### Transformative Technology

- Zero distance between building owner and service provider with what’s on the roof
- Installation and service quality are transparent
- Equipment flaws also transparent
FDD Project 6: SpeciFlow™ Technology
Project Lead: Federspiel Controls

- On the market: Greenheck Fan Corp IAQ-42
- High accuracy damper monitoring & control
- Peak savings from OA control
- LEED credit for OA control
- CA Title 24 Nonresidential compliant
- Integral controller-standalone or DDC

The Future Home of FDD & Remote Commissioning Services?

Midnight phone call from home?
No. It’s RTU #34 at the Commerce Mall reporting low refrigerant pressure. I’ll finish the recommissioning on Monday if the bears don’t get us.

(with apologies to the Notifact website)

Interested in More Information?

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