Hydronic Controls Retrofits for Low-Rise Multi-Family Buildings

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Research Objective

• Determine the impact of control strategies that use apartment temperatures for central boiler control on energy consumption, comfort and cost.

• Compare energy performance, comfort and cost to individual radiator valve controls in each apartment.
Background

• Most multi-family boiler systems have:
  – No zone/apartment level control, or
  – Non-electric thermostats on radiator valves

• Central boiler system resets hot water based on outdoor temperature

• Problem:
  – apartments are often too hot or too cold.
  – Occupants often open windows to “control” temperature
Concept

• New wireless temperature sensors offer the potential to cost-effectively retrofit poorly-controlled heating systems to reduce energy use

• More intelligent boiler plant “reset” control strategies may be more cost effective than full scale retrofits that put zone controls in each apartment.
Test Site - Project Participants

- The ARIES Collaborative, a Department of Energy Building America research team
  - The Levy Partnership, Inc.
  - CDH Energy Corp.
- Homeowners' Rehab Inc., a non-profit housing developer in Cambridge, MA.
- Massachusetts Low Income Multi-Family Retrofit Program (LEAN), a utility program proving funding for the retrofit
- EnerSpective, Inc., assessing the project for the utility program
Test Site

- 42-unit complex of three, three-story masonry buildings in Cambridge, MA
- Each building has two or three 87% eff space heating boilers (+one boiler for DHW)
Technical Approach

- **PHASE I**: Replace boiler controls with wireless system that supplies heat based on both apartment and outdoor temperatures. Rigorously quantify the effectiveness of this strategy.

- **PHASE II** (tentative, TO3): Install radiator zone valves centrally controlled wirelessly using space temperature data.
PHASE I: Indoor Temperature Based Boiler Control

• Wireless temperature sensors in apartments - data used to adjust building supply water temperature
• Web-enabled. Off-site server stores data and makes it available on a website
• Adaptive and intelligent reset and night setback approaches
• Where required, maintain boiler return water temperatures above 140°F with new 3-way mixing valve
• Goals:
  – Reduce spacing heating energy by 15% to 20%
  – Maintain space temperatures closer to the required set points (reduce overheating)
PHASE II: Local Radiator Controls

- Central control of individual radiator risers
- Remove existing, mostly failed, non-electric radiator zone valves
- Install new valves in the basement risers,
- Goal:
  - Obtain additional heating energy savings
  - Distribute only the amount of heat needed at each riser in order to maintain the minimum heat needed in the apartment(s) served by that riser
System Configuration
Apt Complex Layout

Legend:
# = Address
() = No. Apartments
[BR] = Boiler Room
● = No. Risers
Current Zone Controls

- Each apartment has 1-2 non-electric, remote “thermostats” to regulate baseboard water flow
- Valve calibration is unknown
- Many have failed in open position (resulting in overheating)
- Residents typically disregard municipally mandated set points (68°F day, 64°F night)
Boiler Controls

- Both Buildings have Outdoor Reset control
- Supply T about 30°F higher in Bldg 3 on April 7, 2011

Graph:
- HW Supply Temperature (F) vs. Outdoor Temperature (F)
- Bldg 3 Weil McLain
- Bldg 4 Tekmar
- Observed on April 7
Savings & Cost-Effectiveness

- Target: Reduce heating costs by 15% to 25%
- 20% savings = 4,539 therms per year ($5,447 at $1.2/therm)
- Initial Assumption: cost to install the control system (PHASE 1) was $25,000
- Simple payback is 4-5 years
- Payback is longer due to small size of building and multiple boiler rooms
Adjusted Test Plan

• BUILDING 3: Wireless, Web-enabled system (Intech 21)
  – Full functionality
  – Web-based data collection

• BUILDING 4: Updated Baseline system (tekmar)
  – Standard controls, boiler protection valve
  – Data collection capabilities
Baseline Performance

Load line of monthly gas use vs. temperature
2005-2011

DHW Baseline Use
Data Collection (Intech 21)

- Web-enabled control will be used to collect data at 15-minute intervals:
  - Apartment temperatures
  - Outdoor temperature
  - Hot water supply temperature
  - Hot water return temperature
  - Hot water return temp (entering boilers)
  - Cumulative boiler run time (each boiler)
  - Mixing valve position
  - Cumulative runtime of hot water pump

- Also...
  - Comfort will be gauged by heat complaint reports, surveys and observations of open windows
  - Monthly gas consumption from fuel bills
Test in Various Modes

• Control Modes:
  1. Existing conditions (baseline outdoor reset)
  2. Indoor temperature-based control
  3. Indoor temperature-based control with one-time manual balancing of system using riser valves (one building)

• Spend several weeks in each mode
• Directly compare energy performance and comfort impacts after normalizing for weather
Analysis Approach

• Daily load line analysis relating total boiler runtime to outdoor temperature for each day
• Compare resulting linear trends for different performance periods / control modes to discern impacts
  – Multi-linear regression analysis with dummy variables to determine if the differences are statistically significant
  – Relate monthly runtimes to billed gas use to discern impact on fuel use
Project Status

• Hardware installation is underway
• Expect system (and data collection) to be operational and commissioned for late September
• Switch between operating modes throughout fall-winter season
Summary

• Seek to document that new control strategies are viable and cost-effective in affordable low-rise multifamily buildings in cold climates

• Test program designed to gather quantitative data to verify energy efficiency and occupant comfort
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