Re-Tuning Large Commercial Buildings

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Purpose of Presentation

- Introduce commercial building re-tuning and opportunities to become a user of it
- Understand the differences between re-tuning and other similar processes
- Learn the benefits of re-tuning

Presentation Outline

- Definition of Re-tuning
- Background of Re-tuning
- Projects with Opportunities to Participate
- Identifying and Correcting Operational Faults at Low or No Costs Using the Re-tuning Approach
- Common Operational Faults
- Early Results from Re-Tuning Buildings
- Conclusions

Definitions

- HVAC Retro-commissioning
- HVAC Re-tuning
- HVAC Re-commissioning
- HVAC Continuous Commissioning^{SM}
- Monitoring-Based Commissioning
- All processes above in part relate to setting up control systems to some known design configurations, verifying set points and adding control algorithms

Origins for Re-Tuning

- In 1990s several researcher organizations were developing automated fault detection and diagnostics (FDD) tools – the researchers found that the FDD tools can indeed be used for commissioning building systems
- Also, at the same time Texas A&M University was using a process called continuous commissioning to retro-commission existing buildings
- In 2000s monitoring-based commissioning was being applied at many California campuses

What is Re-Tuning?

- A systematic process to identify and correct building operational problems that lead to energy waste
- Implemented primarily through the building control system at no cost other than the labor required to perform the re-tuning process
- Includes small, low-cost repairs, such as replacing faulty sensors
- Includes identifying other opportunities for improving energy efficiency that require investment
- Might be thought of as a scaled-down retro-commissioning focused on identifying and correcting operational problems – costs less, takes less time, and is faster to perform

Purpose of Re-Tuning

- Improve the building's energy efficiency through low-cost and no-cost operational improvements (mostly control changes)
- Identify opportunities to further increase the building's energy efficiency

- Identify problems requiring physical repair
- Capture the big energy saving opportunities which are often the simplest to correct

Re-Tuning Programs

- Re-tuning training was originally offered in Washington State as part of a project funded by the state (www.retuning.org)
  - Uses classroom and hands-on field training
- U.S. Department of Energy is extending training beyond Washington (www.pnl.gov/buildingretuning)
  - Train-the-trainer
  - Work with organizations with large portfolio of buildings interested in learning the re-tuning process
- Currently recruiting participants
- Online interactive training is under development

Seven Primary Steps of Re-Tuning

- Collecting Initial Building Information: Basic building information
- Pre-Re-Tuning Phase: Trend-data collection and analysis
- Building Walk Down: Getting to know the building
- Re-Tuning: Identifying and correcting operations problems
- Post Re-Tuning: Reporting re-tuning findings
- Savings Analysis: Determining and reporting the impacts
- Continue to use re-tuning tools and processes in day-to-day building operation

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Basic Building Information

Contact Information

1. Name: *
2. Company: *
3. Street Address: *
4. City: *
5. State: - Select a State - *
6. Zip Code: *
7. Phone Number: *
8. Email Address: *

Building Information

8. Building Name: *
9. Building City:
10. Building State: - Select a State -
11. Type of Building: - Select a Building Type -
12. Approximate Size (gross ft^2):
13. Utility company providing electric and gas service:
14. Does the building have its own electric meter or is it on a meter that serves multiple buildings?
    - Individual building meter
    - Meter that serves several buildings
    - Don't know
15. Type of Control System:
    - Pneumatic
    - Direct digital
    - Mixed
16. Building Automation System? No / Yes
17. Building automation or control system description:
    (Manufacturer, series and model if known)
18. Can you remotely connect to the system?
    - No
    - Yes, via dial-up modem
    - Yes, via the Internet
    - Don't know but will find out
19. HVAC System:
    (Example: Central heating and cooling, large packaged systems, other)
20. Estimate age of building control/automation system (yrs):
21. What type of service does your company provide to this building?
22. Does your company have a service contract for this building?
    No / Yes
    (Please explain.)

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Trend-Data Collection & Analysis: Purpose

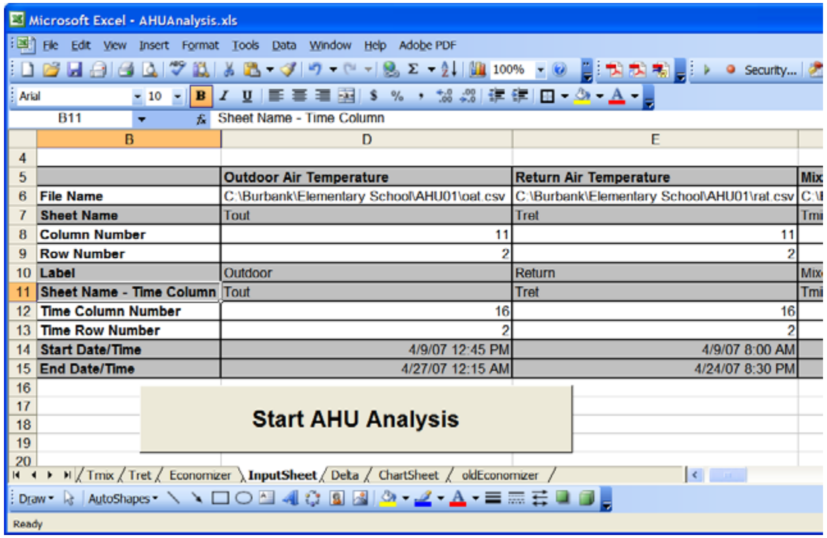
- Detect potential operational problems even before visiting the building
- Identify problems that require time histories to detect – incorrect schedules, no use of setback during unoccupied modes, poor economizer operation

Steps for Trend Data Collection

- Develop a monitoring plan – develop forms to guide service providers. Plan includes the points to trend and for each point:
  - Planned trend start time
  - Planned trend end time
  - Length of measurement period (2 weeks recommended)
  - Time interval between logged measurements (30 minutes or less recommended)
  - Measurement units (e.g., ^{o}F for temperature)
- Implement trend logs in control system

Analyze Trend Log Data – Major Steps

- Download trend log data files from BAS
- Format data files for compatibility with the spreadsheet analysis tool
- Open data files in spreadsheet analysis tool and automatically generate graphs



- Review graphs to identify operational issues
- Record operational issues for reference during re-tuning

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Building Walk Down: Purpose

- Get to know the building better
- Develop a general impression of:
  - Overall building condition
  - Overall building design
  - HVAC system design
- Collect some basic data on the building systems at a level of detail greater than the initial data collection

Building Walk Down: Major Steps

- Review electrical and mechanical prints
- Walk the outside of the building
- Walk the inside of the building
- Walk down the roof
- Walk down the air handlers
- Walk down the plant area
- Review the DDC system (BAS) front end

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Using the knowledge learned from trend-data analysis and building walk through to start re-tuning

Major Focus Areas in Re-Tuning

- Occupancy scheduling
- Discharge-air temperature control
- Discharge-air static pressure control
- Air-handling unit (AHU) heating & cooling
- AHU outside/fresh air makeup
- AHU economizer operation
- Zone conditioning
- Meter profiles
- Central plant

Occupancy Scheduling

- Shut off systems whenever possible
  - Night unoccupied schedules
  - Weekend unoccupied schedules
  - Daytime no or low use unoccupied schedules
    - Auditorium, class rooms, conference rooms
  - Includes lighting
  - Includes specialized exhaust
  - Do not restart too early
    - Use a startup schedule based on building needs
  - Do not use fresh air during warm-up except last 30 minutes for flushing building

Occupancy Scheduling (continued)

- Shut off systems whenever possible
  - Refrain from starting up system for the occasional nighttime user or weekend user
  - Use bypass buttons
- Unoccupied mode is a major cost saver
  - Simple to implement
  - Simple to track
  - Simple to administer
- Sometimes the least paid employee is the most costly
  - Janitors working at night with all HVAC running, all fresh air open & lights on
  - Is this required?

Occupancy Scheduling (continued)

- When running at night for warm up, cool down, or maintaining temperatures, do not ventilate (no outside air)
- Run static pressure at ½ of normal set points, if it does not affect reheat controls
  - Check to make sure heated areas get full air in unoccupied modes
  - Push unoccupied mode air to where it is needed
    - Set VAV boxes in interior zones to unoccupied with 0 air flow
    - Set VAV boxes with reheat to a high air flow in unoccupied mode, so box will be 100% open during night cycling
      - Air gets to zones needing heat

Occupancy Scheduling (continued)

- Building electric consumption should show significant energy drop for nights/weekends
  - Signifying setbacks are active on all HVAC systems
  - Base load versus peak loads should be at least 30% difference and as much as 50% with aggressive setbacks
- Trended data for zone temps should show 5-10^{o}F deviations from set points when setbacks are active during non-shoulder months
  - Winter zone temps should drop down to 60-65^{o}F and summer zone temps should rise to 80-85^{o}F

Occupancy Schedule (continued)

- Trended data for discharge static pressures should show readings of 0" or at least 50% (half) of normal (occupied) static pressure readings
- Trended data for main supply/return fan status should indicate "OFF" during unoccupied periods
- Trended data for VAV boxes occupied status should indicate "Unoccupied" during unoccupied periods
- Trended data for support systems (reheat pumps, reheat converters, reheat hot water boilers, chillers, towers, pumps, etc) should indicate they are turning off at night, if all areas of the building are also shut down

Occupancy Schedule (continued)

- Unoccupied periods should include weekends, holidays and night hours during work week periods
  - If facility has sporadic use periods, this may require additional efforts to succeed at implementing setbacks
- Make sure the “tail” is not “wagging the dog” – janitors, special events, extreme weather events, overrides, etc
- How does your organization respond to trouble calls (occupant complaints)? How do you respond? Is the response a “band-aid” or a long-term solution? Overrides on schedules are not long-term solutions

Occupancy Schedule (continued)

- Empower occupants to control their ventilation when they need it
  - Most building designs provide occupants with local light switches for local lighting control
  - Does your DDC system provide similar capabilities for ventilation so occupants can obtain ventilation automatically when they need it (motion sensors, timed overrides, calendar scheduling of conference rooms or other "special" spaces)?
- Consider adding outdoor-air temperature interlocks that "override" the occupied schedule, anytime the outdoor-air temperature exceeds the design parameters
  - This will eliminate overrides that are left in place and should only be active 2-4 weeks/year
- Does your DDC system have "scheduling" capability?
  - Do you know how it works?
- Does your DDC system have "Optimal Start" scheduling capability?
  - Are you using it?

Example of AHU Schedule Trend

Sample Time (Trend 1)	SF3_STATUS
11/17/2007 0:00	Off
11/19/2007 1:00	On
11/19/2007 17:00	Off
11/20/2007 2:00	On
11/20/2007 17:00	Off
11/21/2007 2:00	On
11/21/2007 17:00	Off
11/23/2007 2:00	On
11/23/2007 17:00	Off
11/26/2007 1:00	On
11/26/2007 17:00	Off
11/27/2007 2:38	On
11/27/2007 17:00	Off
11/28/2007 2:00	On
11/28/2007 5:24	Off
11/28/2007 5:26	On
11/28/2007 5:55	Off
11/28/2007 6:00	On
11/28/2007 17:00	Off
11/29/2007 2:00	On
11/29/2007 17:00	Off
11/30/2007 2:00	On
11/30/2007 10:48	On

Zone Heating and Cooling Demands

- Purpose
  - Get a feel for how many zones on each monitored air handler are heating and how many are cooling at the same time
  - Get a sense of which areas are heating and which are cooling at any given time
  - Determine if any individual zones are heating and cooling at the same time
  - Others?

Zone Heating and Cooling Demands (continued)

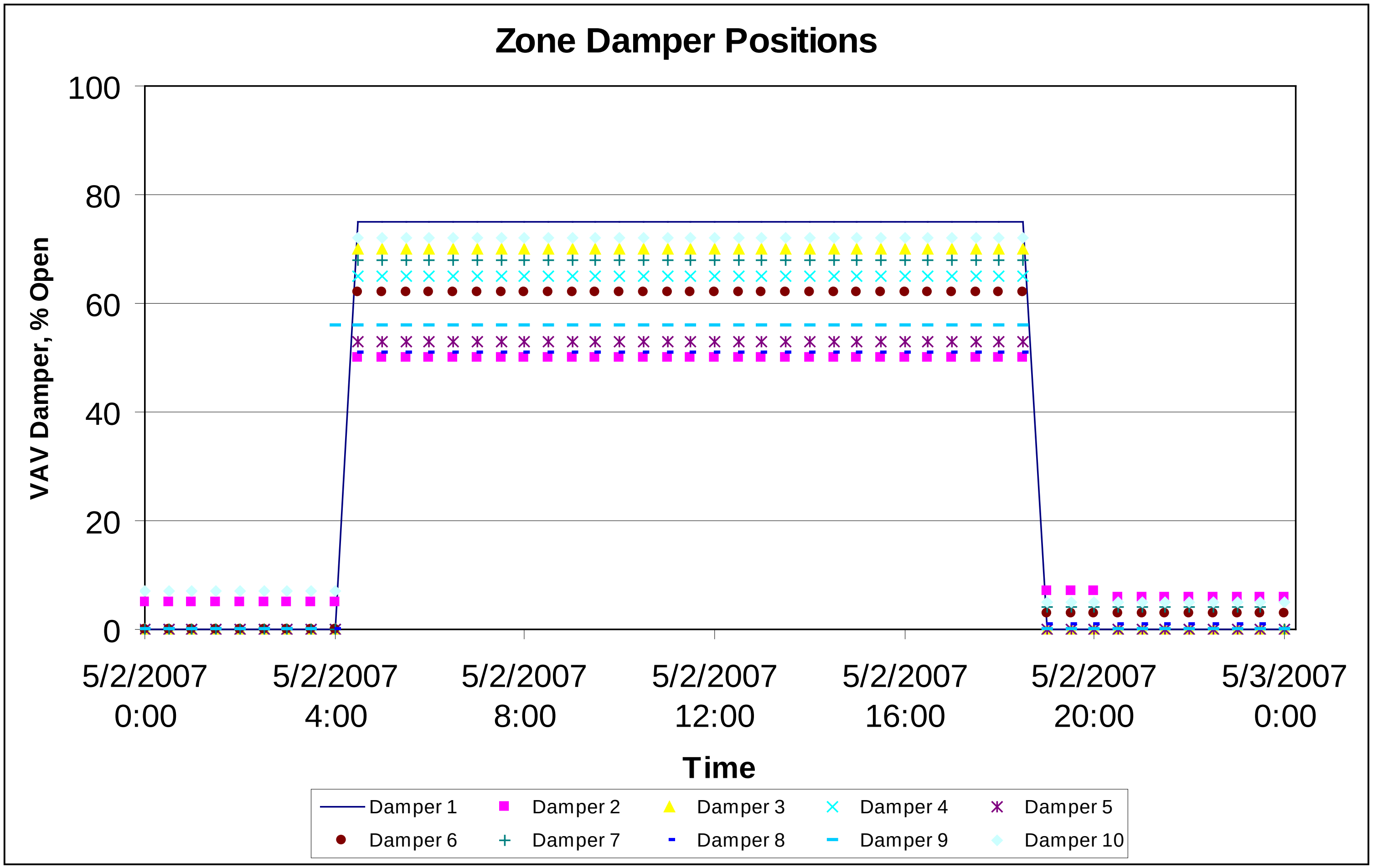
- Approach
  - For each air handler, count the number of zones served that are in heating mode and those in cooling mode under various conditions (e.g., time of day and approximate outdoor air temperature). Use a plot of number of zones in each mode and the outdoor temperature vs. time
  - Note which areas of the building (e.g., interior core vs. perimeter zones or zones facing certain directions) are in heating and cooling
  - Look for any monitored zones that are using both heating and cooling over relatively short time periods or cycling between heating and cooling

Zone Heating and Cooling Demands (continued)

- Potential issues to identify
  - Supply-air temperature too cool or too warm
  - No use of supply-air reset
  - Certain zones (e.g., corner offices) driving air handler operation
  - Some zones out of control, oscillating between heating and cooling
  - Others

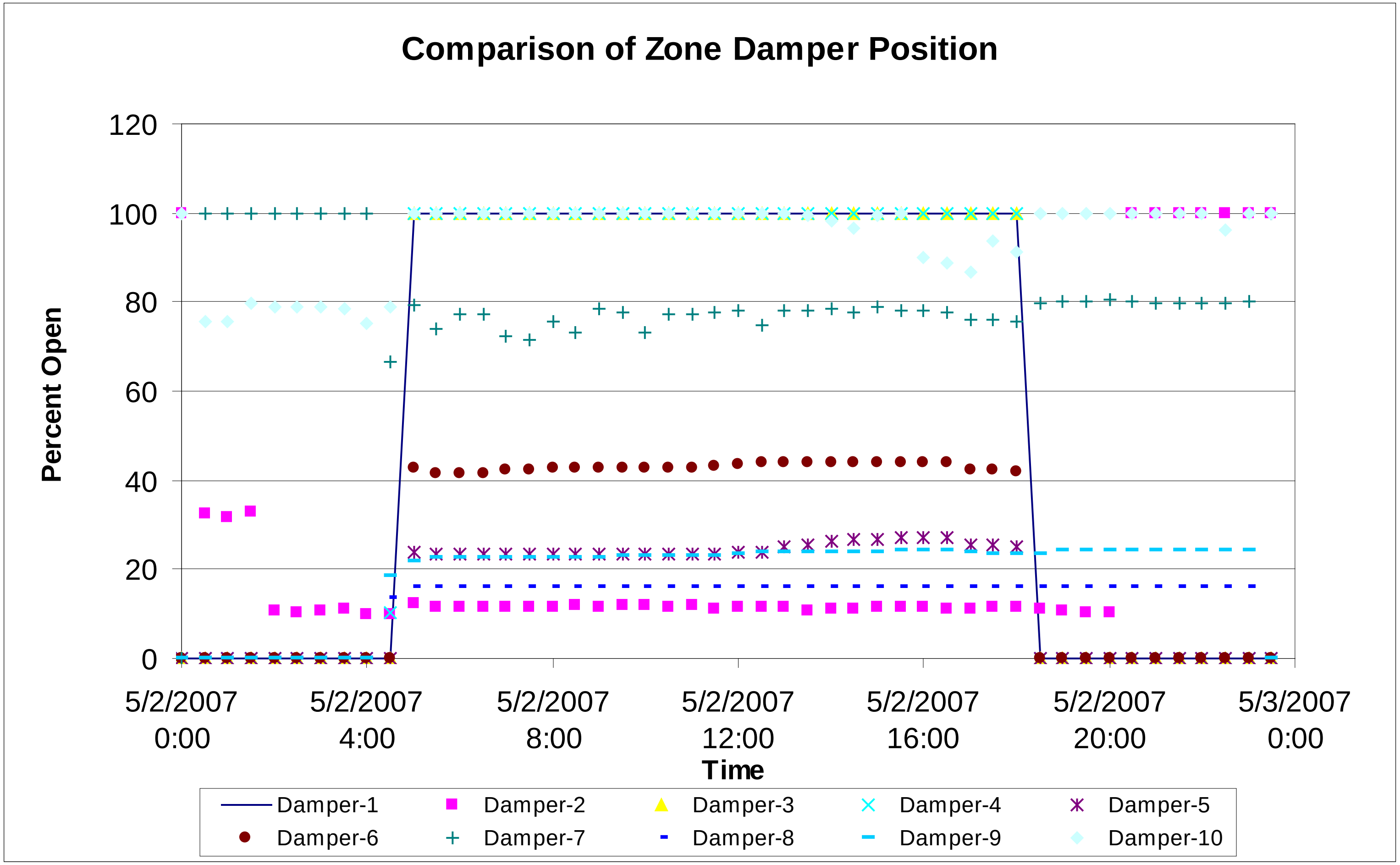
Zone Heating and Cooling Demands (continued): Example Use of Graphs

Plot of VAV unit dampers vs. time for all VAV units served by an air handler – **Very Good Distribution – Most 50% to 75% open**



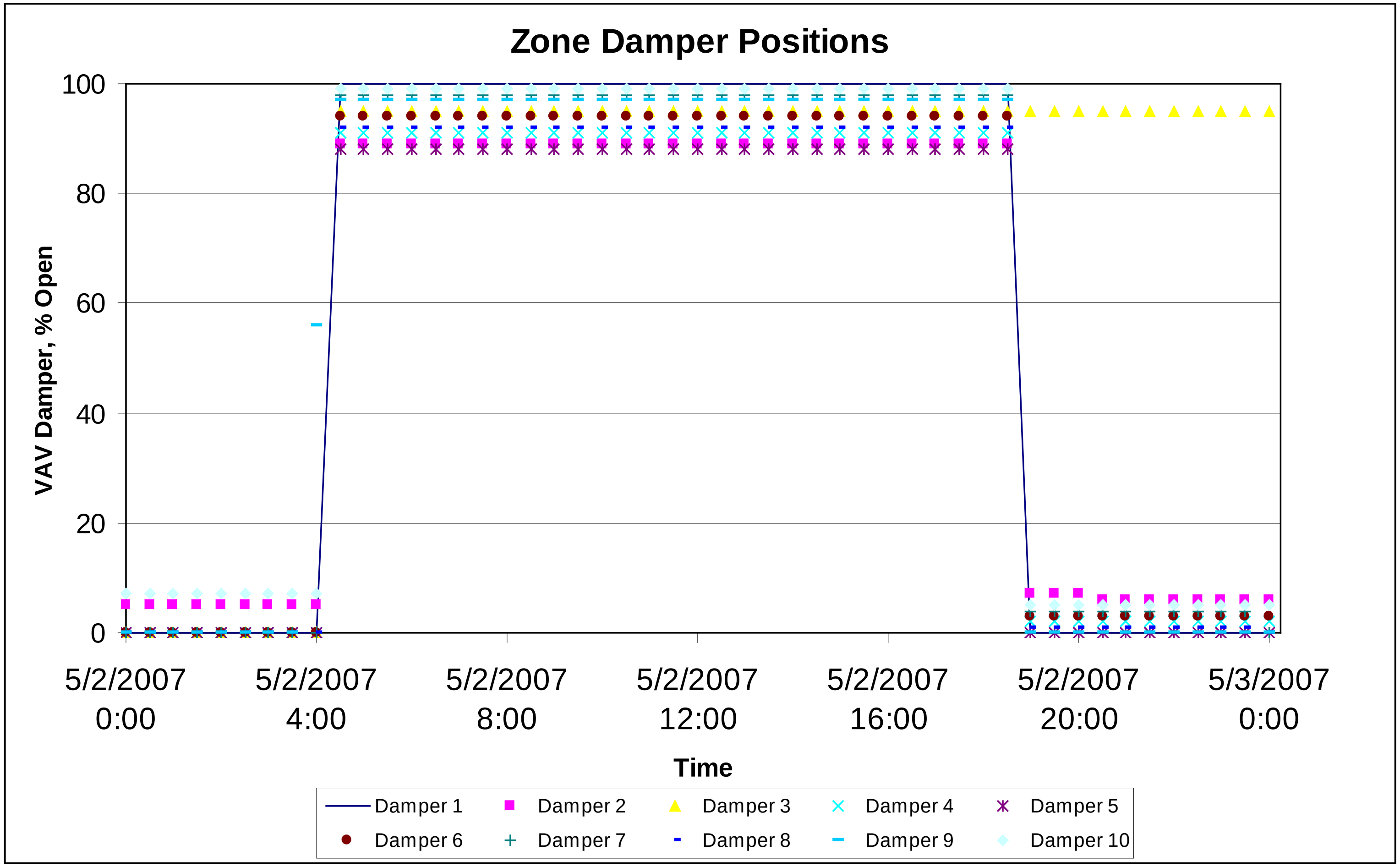
Zone Heating and Cooling Demands (continued): Example Use of Graphs

Plot of VAV unit dampers vs. time for all VAV units served by an air handler – **Distribution Marginally OK**



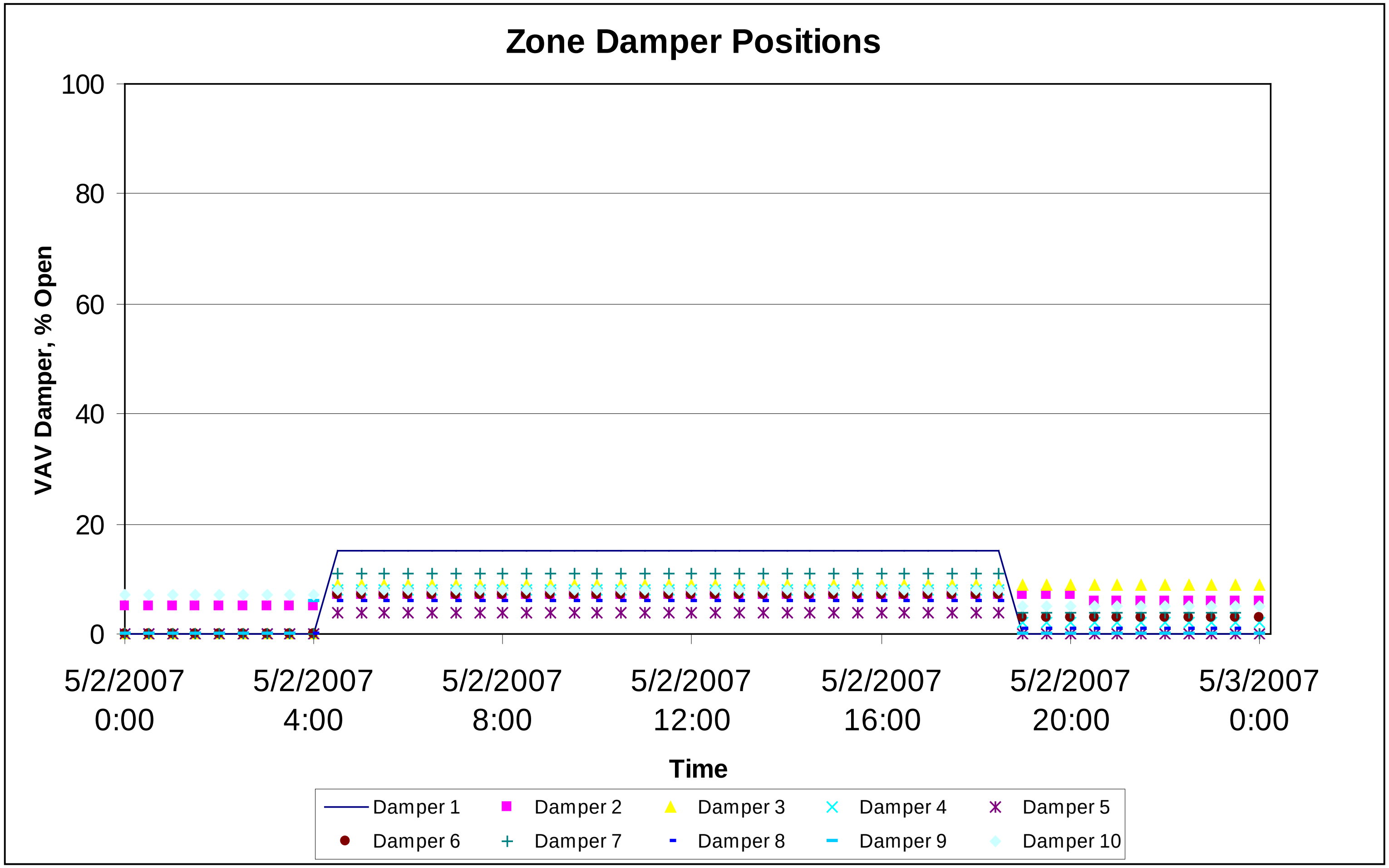
Zone Heating and Cooling Demands (continued): Example Use of Graphs

Plot of VAV unit dampers vs. time for all VAV units served by an air handler – **Bad Distribution – Too many near fully open**



Zone Heating and Cooling Demands (continued): Example Use of Graphs

Plot of VAV unit dampers vs. time for all VAV units served by an air handler – **Bad Distribution – Too many near fully closed**



Highlights of Re-Tuning

- Every set point adjustment made will have an impact of some sort on the utility meter
- Can save energy and keep occupants comfortable
- It takes time to tune a building
- There are no magic set points that work all the time
- Always monitor the utility meters (gas & electric) to see what affect you have had
- Look at the big picture when making adjustments
- Watch the meter profiles weekly
- Learn and know the building's personality

Highlights of Re-Tuning

- Re-tuning approach has found a number of “no-cost” and “low-cost” operational changes that could result in significant savings (>5% of the total consumption) in almost all buildings used for field training

Common Problems Based on Re-Tuning 20 Buildings

Type	Problem	Number of Buildings	Fraction of Buildings, %
Controls	Systems running more hours than needed	6	30
	Improper economizer operations	6	30
	Outdoor-air is not reset to zero during morning warm-up or cool-down	5	17
	Optimal start/stop not working or not present	4	20
	Tight dead band (1°F), causing excessive cycling between heating and cooling modes	3	15
	Building unoccupied during summer months, but all systems running during that period	3	15

List of Common Problems (cont.)

Type	Problem	Number of Buildings	Fraction of Buildings, %
HVAC Systems	No chilled water or hot water reset	6	30
	Leaky valves	3	15
	Static pressure too high	2	10
	Exhaust fans on 24 x 7	2	10
	No static pressure reset	2	10
Building	Un-insulated chilled/hot water pipes or missing attic insulation	4	20
	Missing door/window seals	3	15
	Faulty sensors	2	10
Lighting	Some areas over lit	4	20
	Lack of occupancy sensors in common areas	3	15

Issues for Successful Application of Re-tuning

- Important to make adjustments during the re-tuning process. Do not defer implementation until later.
- Building operations staff need to know that they have the authority to implement minor operational changes without risk of reprisal
- Building operation staff need to have confidence in the process. To develop comfort, operators can make small incremental changes over time and observe the response of occupants.

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- **Savings Analysis: Determining and reporting the impacts**
- Continue to use re-tuning tools and processes in day-to-day building operation

Post-Re-Tuning: Calculating Energy Savings – Overview of Approach

- Calculated as the difference between the actual energy use in the post-re-tuning 12 months and the energy use that would have occurred during the same 12 months if the building had not been re-tuned.

$$E_{savings,j} = E_{base,j} - E_{actual,j}$$

$E_{savings,j}$ = energy savings for a specific building (j)

$E_{actual,j}$ = actual measured energy use of the building during the 12 months after re-tuning

$E_{base,j}$ = energy consumption of the building during the 12 months after re-tuning if it had not been re-tuned

The Most Important Step of the Seven Primary Steps of Re-Tuning

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Benefits of Re-Tuning as Part of Operation

- Systems and equipment are maintained in proper operating condition
- Persistence of savings is assured – dollars and energy
- Operational faults will not accumulate
- Occupant complaints will decrease

Questions?

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Retuning Information at:

http://www.pnl.gov/buildingretuning/

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Economizer Operation

- Purpose
  - To determine whether air-side economizers are operating properly
    - Do economizers open, close, and/or modulate under appropriate conditions?
    - At what temperature compared to the discharge temperature?
    - At what apparent control signal values do the economizers open?
    - Does the cooling coil operate (chilled water flow) during economizing?

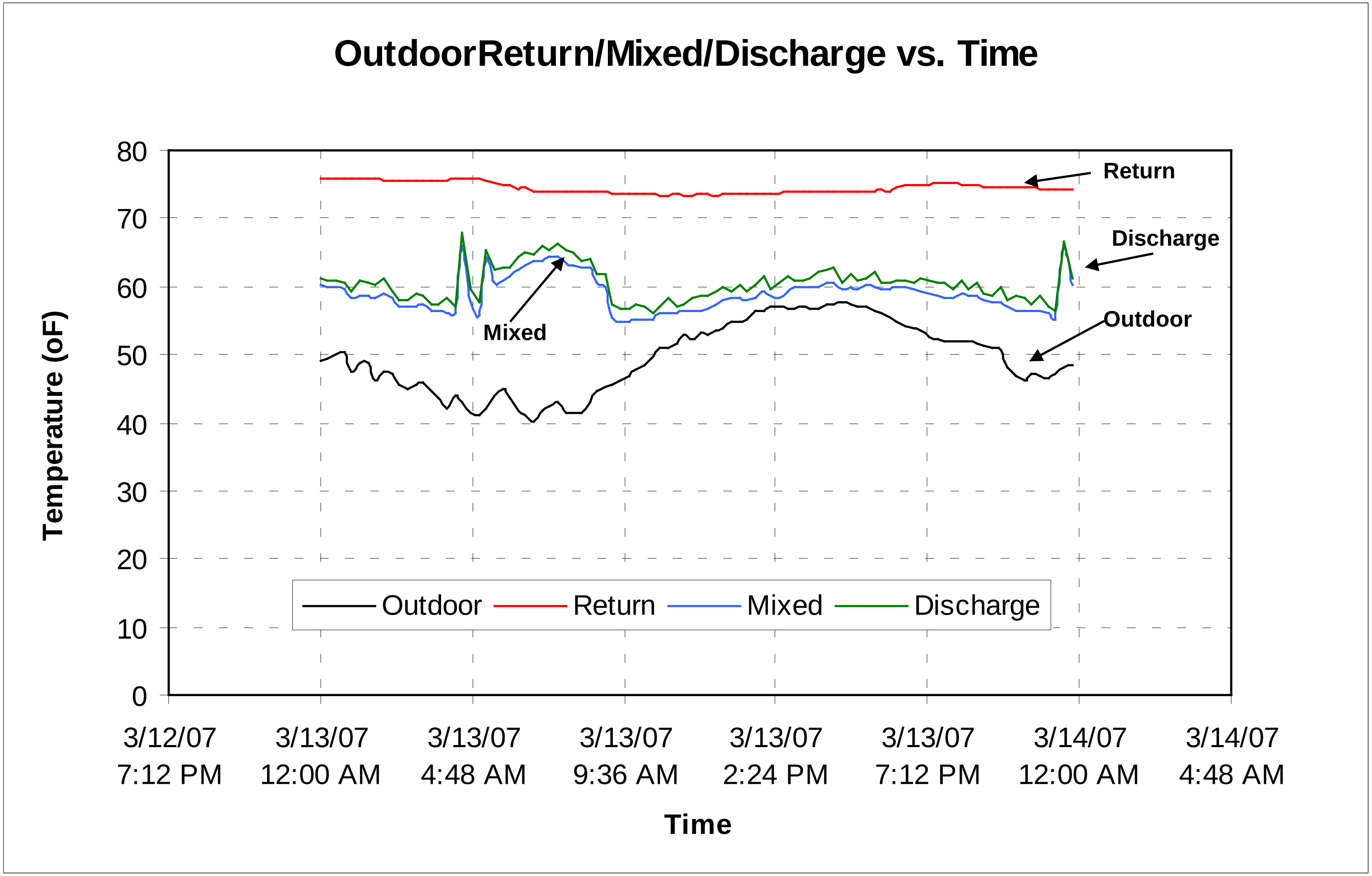
Economizer Operation (continued)

- Approach
  - For each air-side economizer, review plots of:
    - Outdoor-air temperature, mixed-air temperature, return-air temperature and discharge-air temperature vs. time
    - Outdoor-air damper position (% open), outdoor-air temperature, and return-air temperature vs. time
    - Outdoor-air damper position and chilled-water valve position (% open) vs. time
  - Look for outdoor-air dampers (economizer) open at unusual times of day or under unusual outdoor temperature conditions
  - Look for outdoor-air dampers not open to economizer under favorable conditions (outdoor-air temperature between 40°F and 60°F)
  - Look for outdoor-air damper not closing to minimum position for freeze prevention when outdoor temperature is less than about 40°F

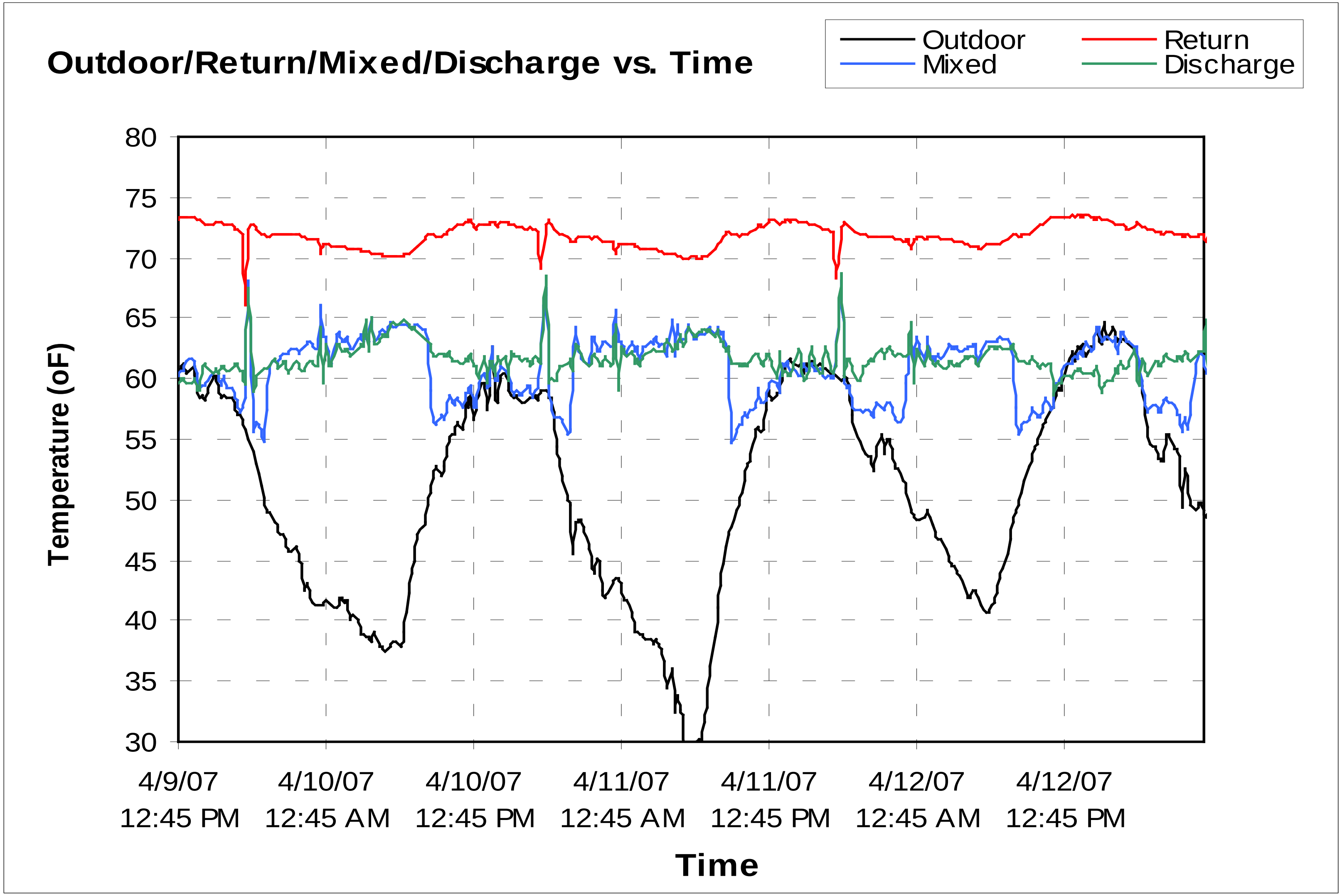
Economizer Operation (continued)

- Potential issues to identify
  - Incorrect economizer operation – numerous causes (identified later during on-site work)
    - Incorrect control strategy
    - Stuck dampers
    - Disconnected or damaged linkages
    - Failed actuator
    - Disconnected wires
    - Failed, uncalibrated or miscalibrated sensors
    - 2 X 4 in damper
    - Others?

Economizer Operation (continued): Example use of Graphs – 1 Day

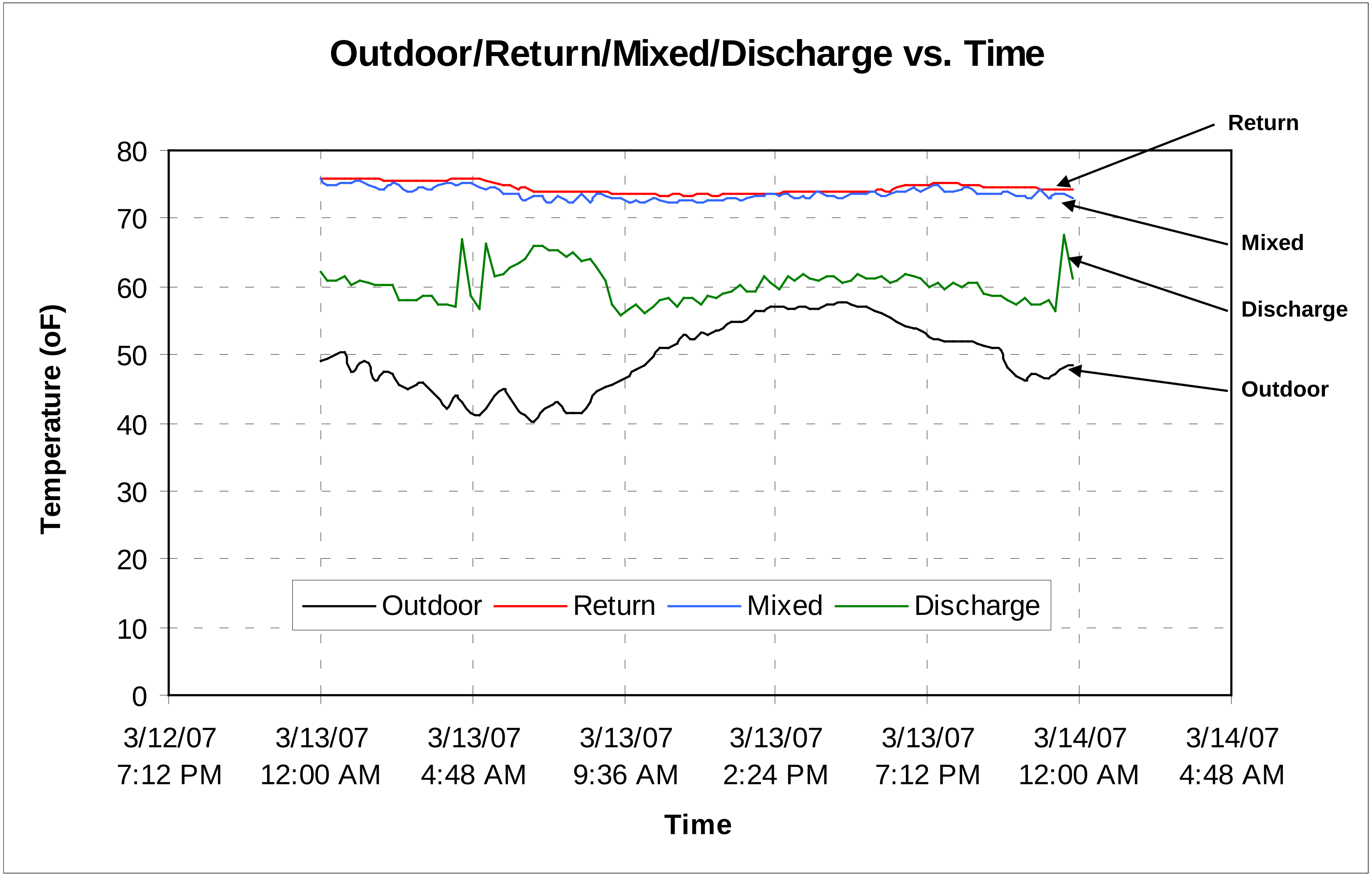


Economizer Operation (continued): Example use of Graphs – 3 Days



Economizer Operation (continued): Example use of Graphs – 1 Day - Faulty

- Outdoor-Air Damper Stuck Fully Closed



Economizer Operation (continued): Example use of Graphs – 1 Day - Faulty

- Outdoor-Air Damper Stuck Fully Open