Pacific Northwest
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Large Commercial Buildings: Re-tuning for Efficiency

Terminal Units in Air Distribution System: Pre-Re-Tuning and Re-Tuning

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Zone Conditioning

- Zone set points
  - Be aware that zone set points drive the system and have a ripple effect all the way to the meter
    - If the zone set points are too low, you can drive the system into cooling mode with excessive reheat
    - If the zone set point is too warm, you will waste energy for heating and use more outside-air makeup due to air handlers using more air
    - One zone can drive multiple zones around it
- Use occupied modes in variable air volume (VAV) controllers
- Install discharge-air temperature sensors on units with reheat whenever possible

Importance of Terminal Units Re-tuning

- Terminal boxes are major building HVAC components and directly impact comfort and energy costs
- Terminal boxes control may cause occupant discomfort and waste energy, if they have inappropriate operation and control
- Improper minimum air flow setting and control may result in significant simultaneous heating and cooling, extra fan power consumption and higher energy consumption in the summer

General Benefits from Re-tuning Zone Terminal Boxes

- Reduce fan power consumption
- Minimize simultaneous heating/cooling
- Reduce occupant complaints & improve thermal comfort
- Reduce deferred maintenance

Classification of Terminal Units

- Unit operation
  - Primary air only / induction unit / fan powered
- Primary air inlet
  - Single duct / dual duct
- Supply air flow
  - Constant air volume / variable air volume
- Control scheme
  - Pressure dependent / pressure independent
- Reheat option
  - With reheat / without reheat
- Fan powered unit
  - Series (constant volume) / parallel (variable volume)
- Related controllers & actuators
  - Pneumatic/electric/direct digital controls

Commonly Used Terminal Units

- Single duct variable air volume (SDVAV) terminal box
  - With reheat (hot water reheat/electrical reheat; typically used in perimeter zones)
  - Without reheat (typically used in interior zones)
- Fan powered unit
  - Parallel type
  - Series type
- Dual duct terminal box
  - Dual duct constant air volume (DDCAV)
  - Dual duct variable air volume (DDVAV)
- Induction units (2 pipe/4 pipe)

Analyze 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?

Analyze Zone Heating and Cooling Demands

- Approach
  - For each air-handler, count the number of zones served that are in heating mode and that are 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

Analyze Zone Heating and Cooling Demands

- 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

Pre-Re-Tuning Phase: Trend-Data Collection and Analysis of Terminal Boxes

- Collect all minimum air flow and maximum air flow settings for pressure independent terminal boxes using the building automation system (BAS) reporting function
  - Purpose is to identify potential of reducing the minimum air flow setting
- Collect all terminal box damper positions and reheat valve positions using BAS
  - Purpose is to identify simultaneous heating and cooling

Selection of Zones for Trending

- Zones with comfort complaints
- Interior zones with low/light cooling load (janitor's room or office storage as examples)
- Zones with high minimum air flow setting (>35% for example)
- Exterior zones with reheat during cooling season
- Office that is no longer fully occupied as originally designed
- Refer to the zone/VAV box monitoring plan/table

Parameters to Trend

- Trend as many points as possible from the following list
  - Discharge-air temperature from AHU
  - Discharge-air temperature after the reheat coil, if possible (if not available, reheat valve position as alternative)
  - Zone air temperature
  - VAV damper position
  - Zone occupancy mode
  - Electrical heater stage or on/off status
  - Outdoor-air temperature is also needed (from BAS)

Zone Data Analysis

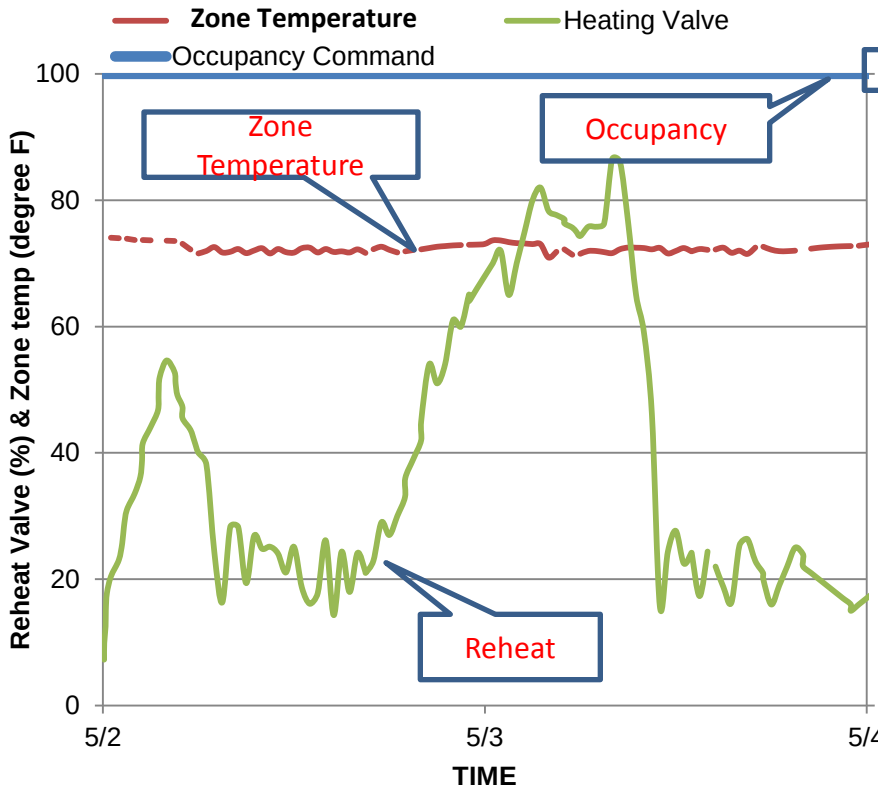
- Key conditions to look for while analyzing the charts:
  - No night time set back
  - Significant reheat for interior zone terminal box during the occupied hours
  - Overcooling or overheating
  - Significant reheat during summer/cooling season for exterior zone box
  - Discharge-air temperature too cool or too warm
  - No use of discharge-air reset
  - Certain zones (e.g., corner offices) driving air-handler operation
  - Some zones out of control, oscillating between heating and cooling

Zone Data Analysis: Unoccupied Mode/Night Set back

- Unoccupied mode, no night time set back for terminal box
  - Determine whether the unoccupied hour is not defined or the time schedule is not enabled
- Approach:
  - Review the plots of zone occupancy command, heating valve or damper position vs. time
  - Look for the valve and/or damper position at unoccupied hour

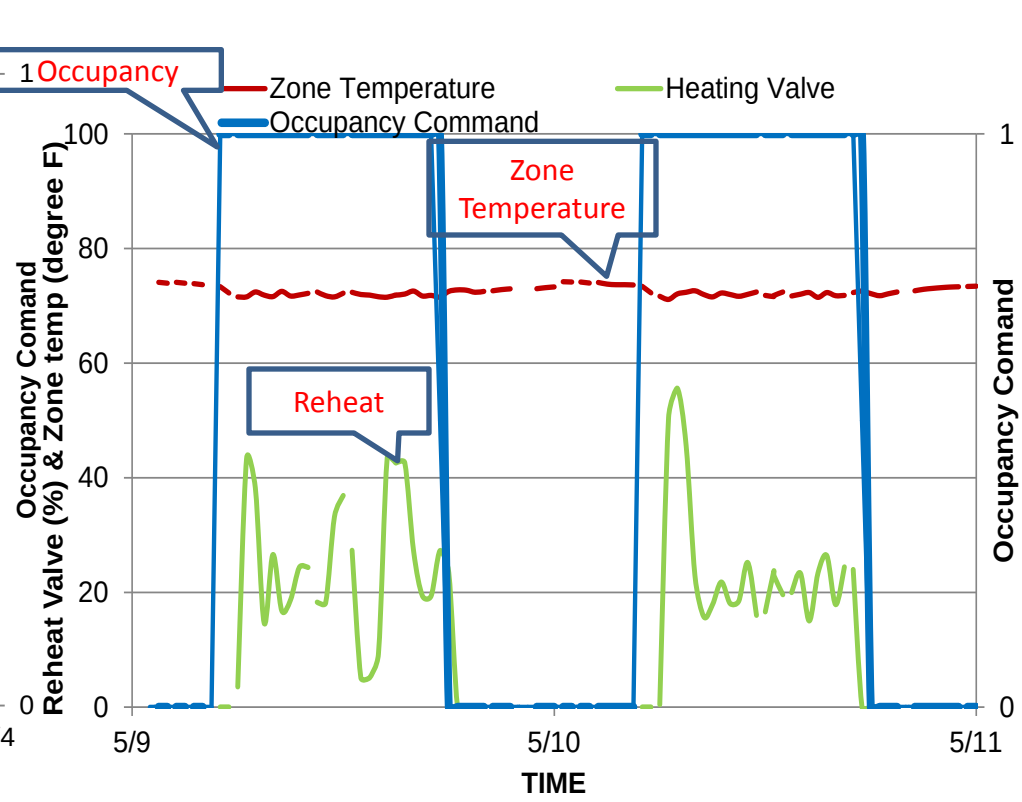
Zone Data Analysis: Unoccupied Mode/Night Set back

- No non-occupancy mode
- Reheat valve modulation at night



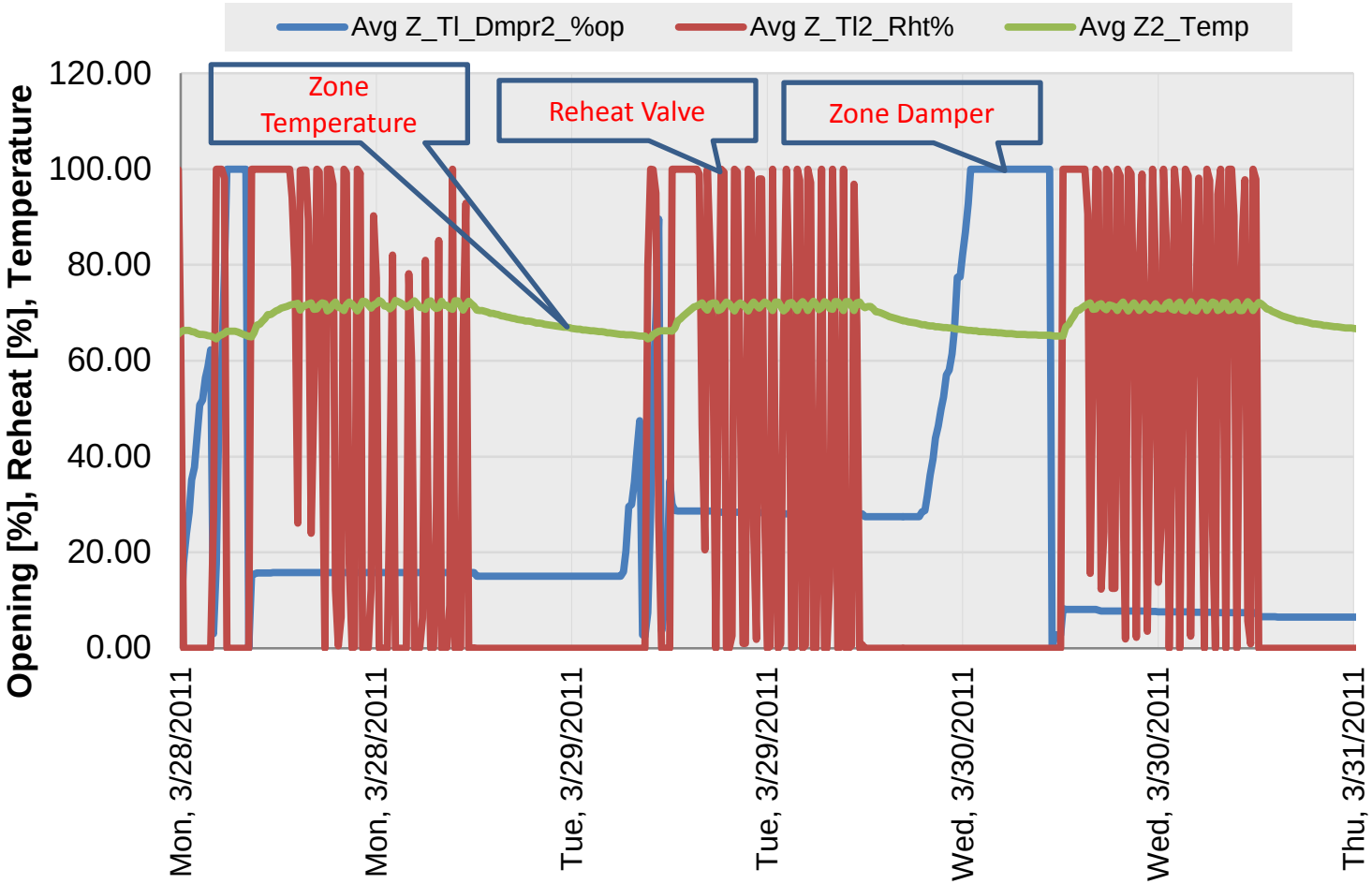
Example of Bad Operation

- There is non-occupancy mode
- Reheat valve off at night

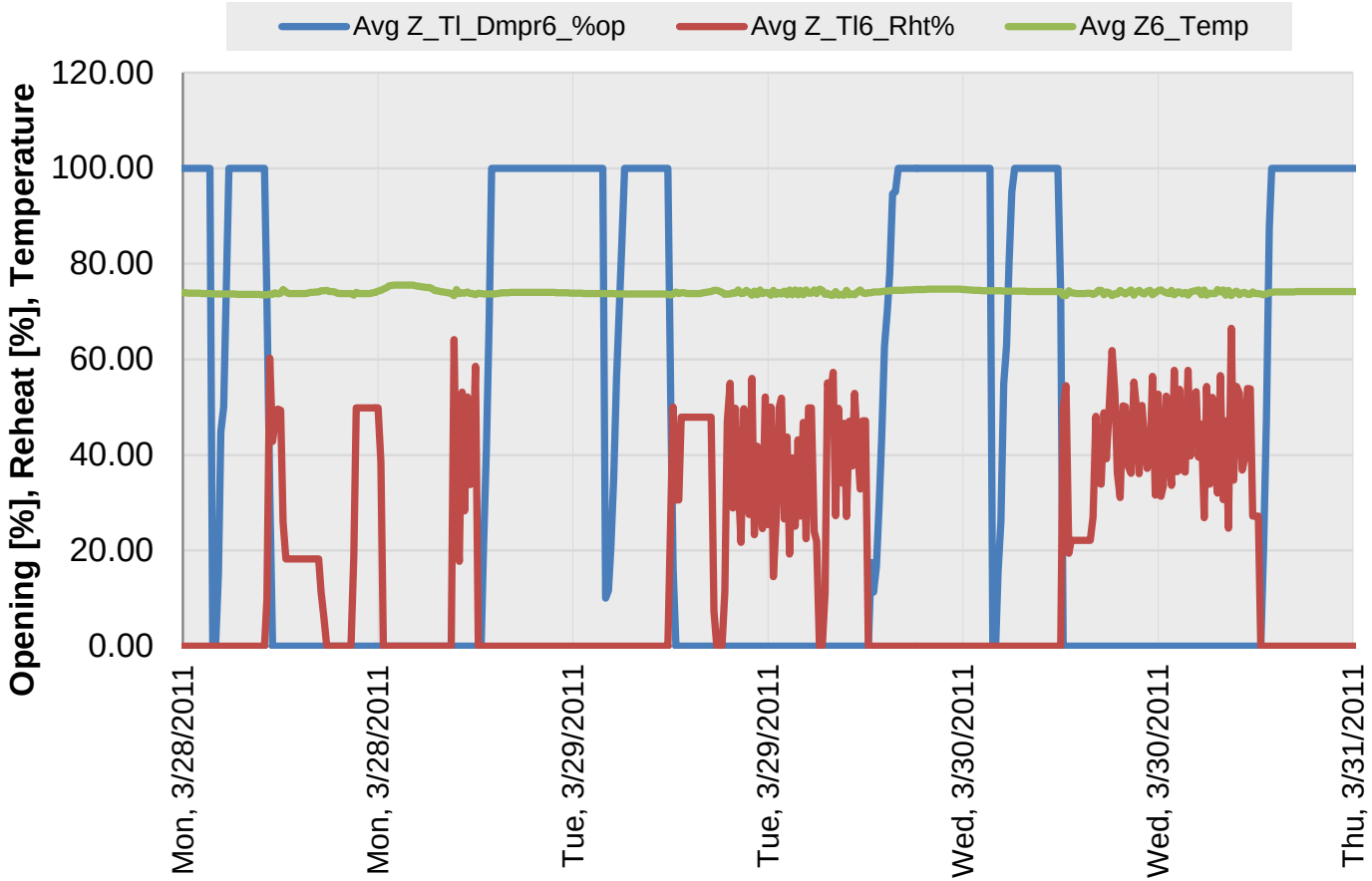


Example of Good Operation

Zone Data Analysis: No Night Time Set Back?



Zone Data Analysis: Fan Powered Box



Re-tuning Recommendations for Unoccupied and Night Set back

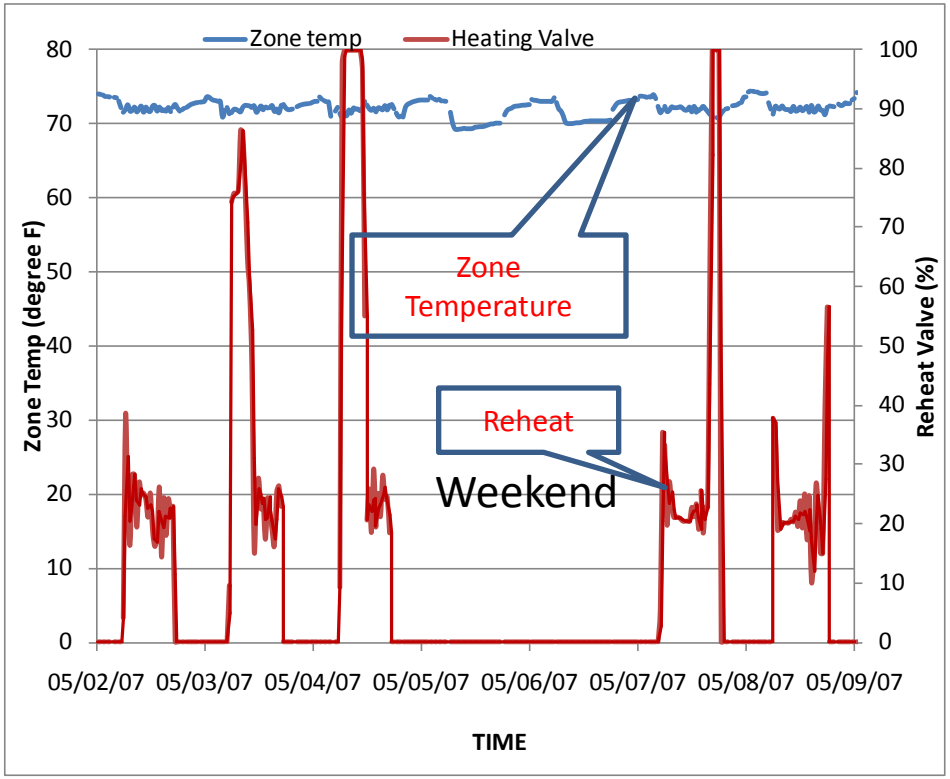
- Enable unoccupied mode and night set back control
- Develop a schedule for each zone
  - Turning OFF systems too early in the evening or turning them ON too late in the morning may cause comfort problems
- Make sure the unoccupied mode is enabled

Reheat for Interior Zone VAV Box

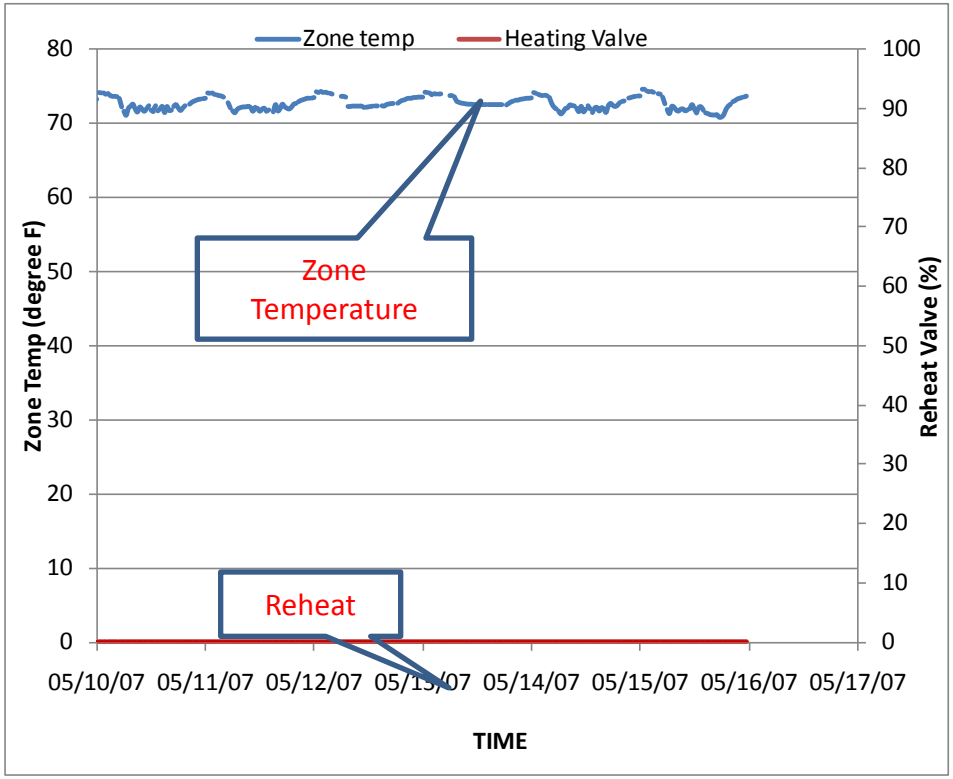
- Minimum air flow setting is too high, leading to excessive reheat
  - Determine whether the heating valve is open during occupied hours during summer time
  - Review the plots of heating valve vs. time (and outdoor-air temperature)

Reheat for Interior Zone VAV Box Example

- Significant reheat for interior zone terminal box with high minimum air flow setting
- No reheat for interior zone terminal box: the minimum air flow setting has been retuned



Example of Bad Operation



Example of Good Operation

Re-tuning Recommendations for Interior Terminal Box Minimum Air flow Setting

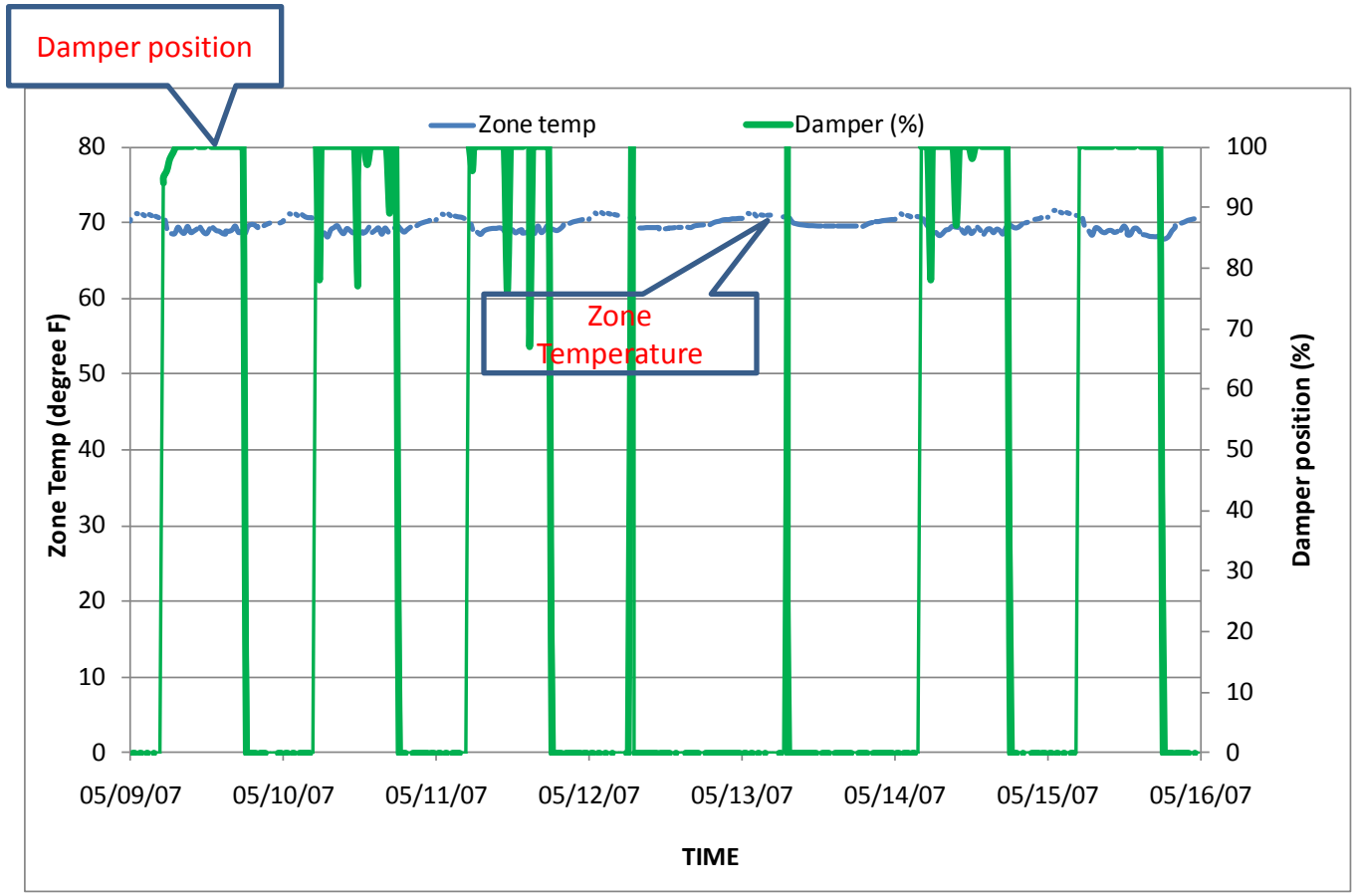
- Reduce interior zone terminal box minimal air flow setting
- Disable heating for interior zones in summer (OAT > 70^{o}F, for example) to eliminate the heating leakage
  - It can be accomplished by the terminal box control programming or building heating system control

Zone Data Analysis: Overcooling

- Case 1: The minimum air flow setting is too high
  - Terminal box damper is forced to open to meet the minimum air flow requirement, although the room temperature set point is satisfied
- Case 2: Terminal box flow station is out of calibration
  - The actual flow is much more than the measured flow

Zone Data Analysis: Overcooling Example

- Starving terminal box for a conference room (space temperature set point is 75°F and no reheat coil

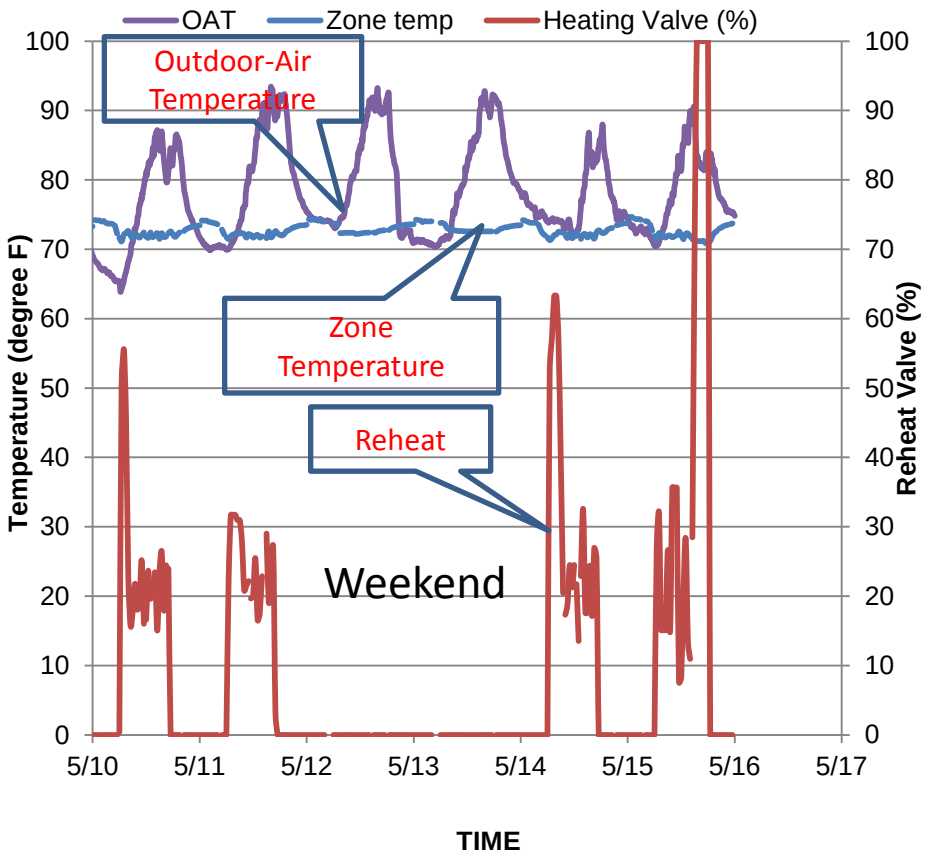


Simultaneous Heating and Cooling for Exterior Zone Terminal Boxes

- Issue: There is significant reheat for exterior zone terminal box during summer
- Purpose:
  - Determine whether the minimum air flow setting is too high
- Approach:
  - Review the plots of outdoor-air temperature and heating valve vs. time
  - Look for the heating valve position when outdoor-air temperature is higher than 65^{o}F

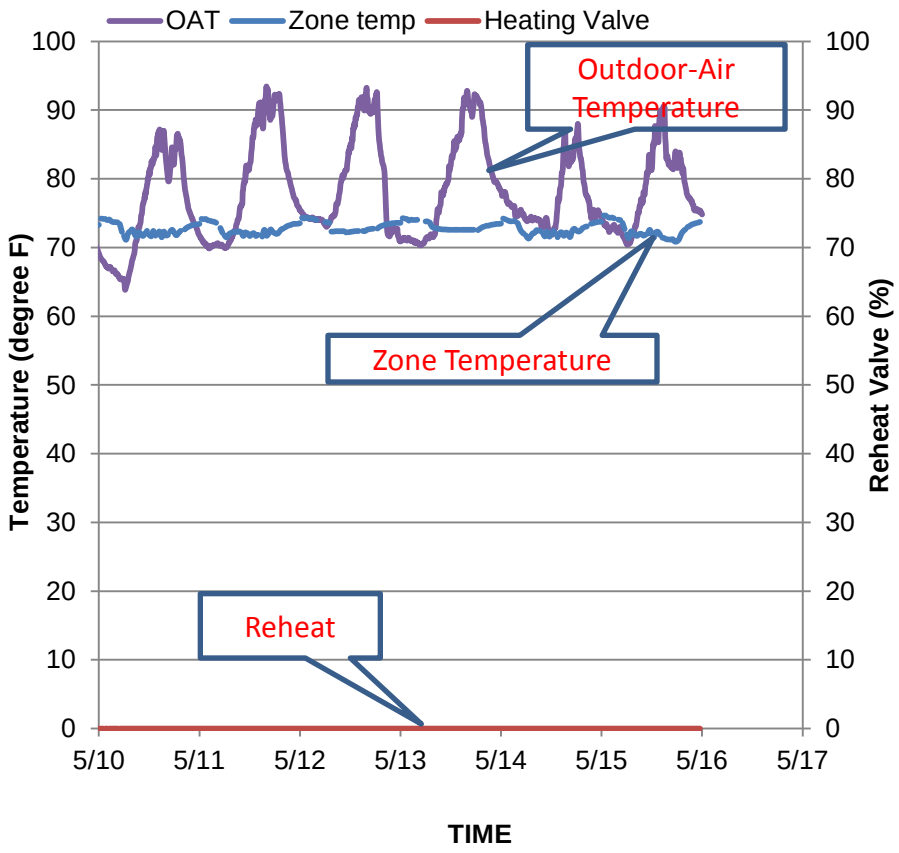
Example of Simultaneous Heating and Cooling for Exterior Zone Terminal Boxes

- OAT>72°F, reheat is still on



Example of Bad Operation

- OAT>72°F, reheat is off



Example of Good Operation

Re-Tuning Recommendations for Exterior Zone

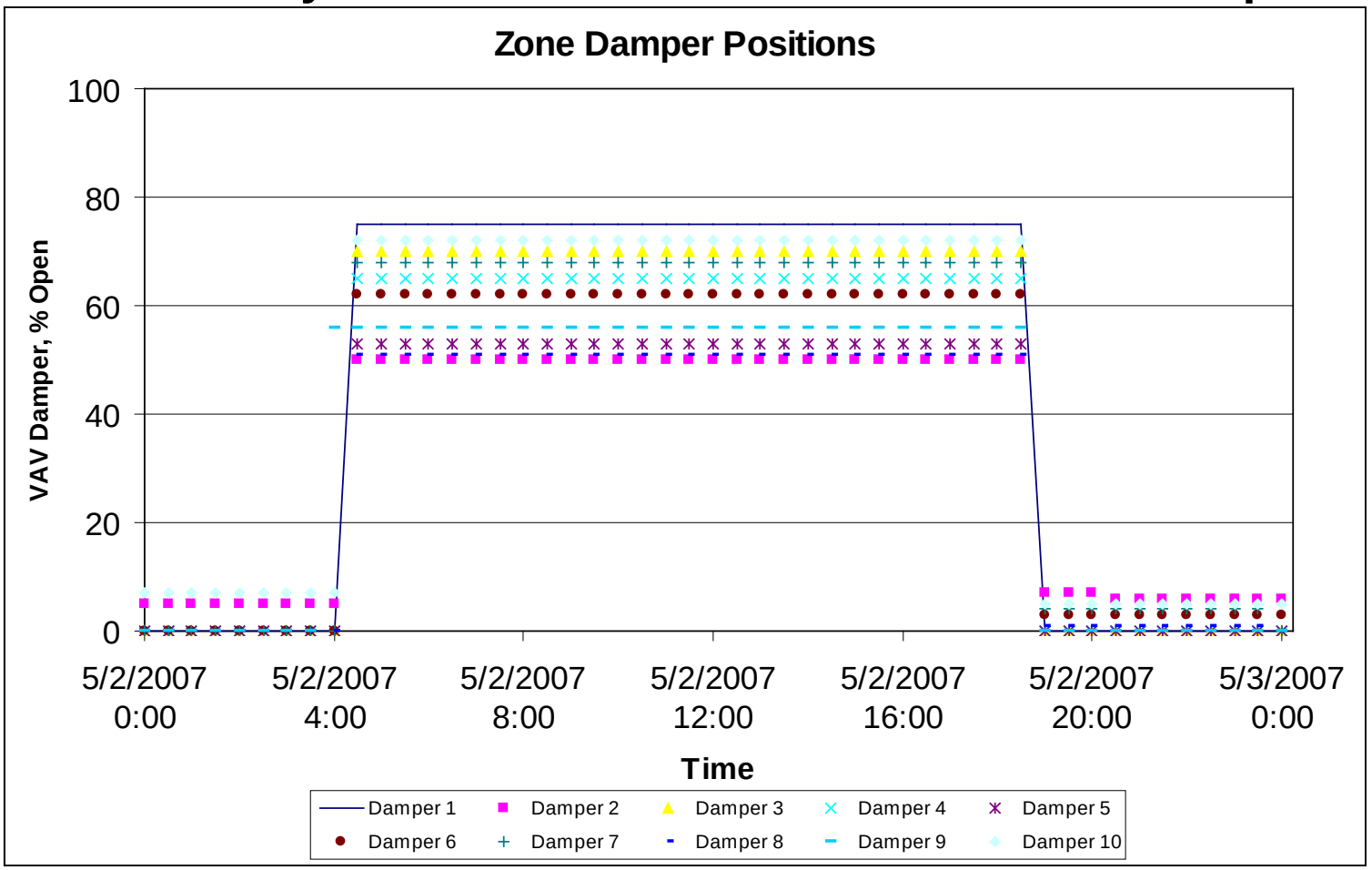
- Reduce the exterior zone terminal box minimum air flow setting based on the ventilation requirements and external wall exposure

Zone Data Analysis: Reheat Valve Leakage

- Issue: overheated space, cooling set point cannot be maintained
- Purpose: determine if the reheating valve is leaking
- Approach:
  - Review plots of air-handling discharge-air temperature (ADAT), zone discharge-air temperature (ZDAT) and zone temperature vs. time
  - Look for temperature difference between ADAT and ZDAT
  - If there is no trended data available for ZDAT, a **spot measurement** at diffuser is recommended

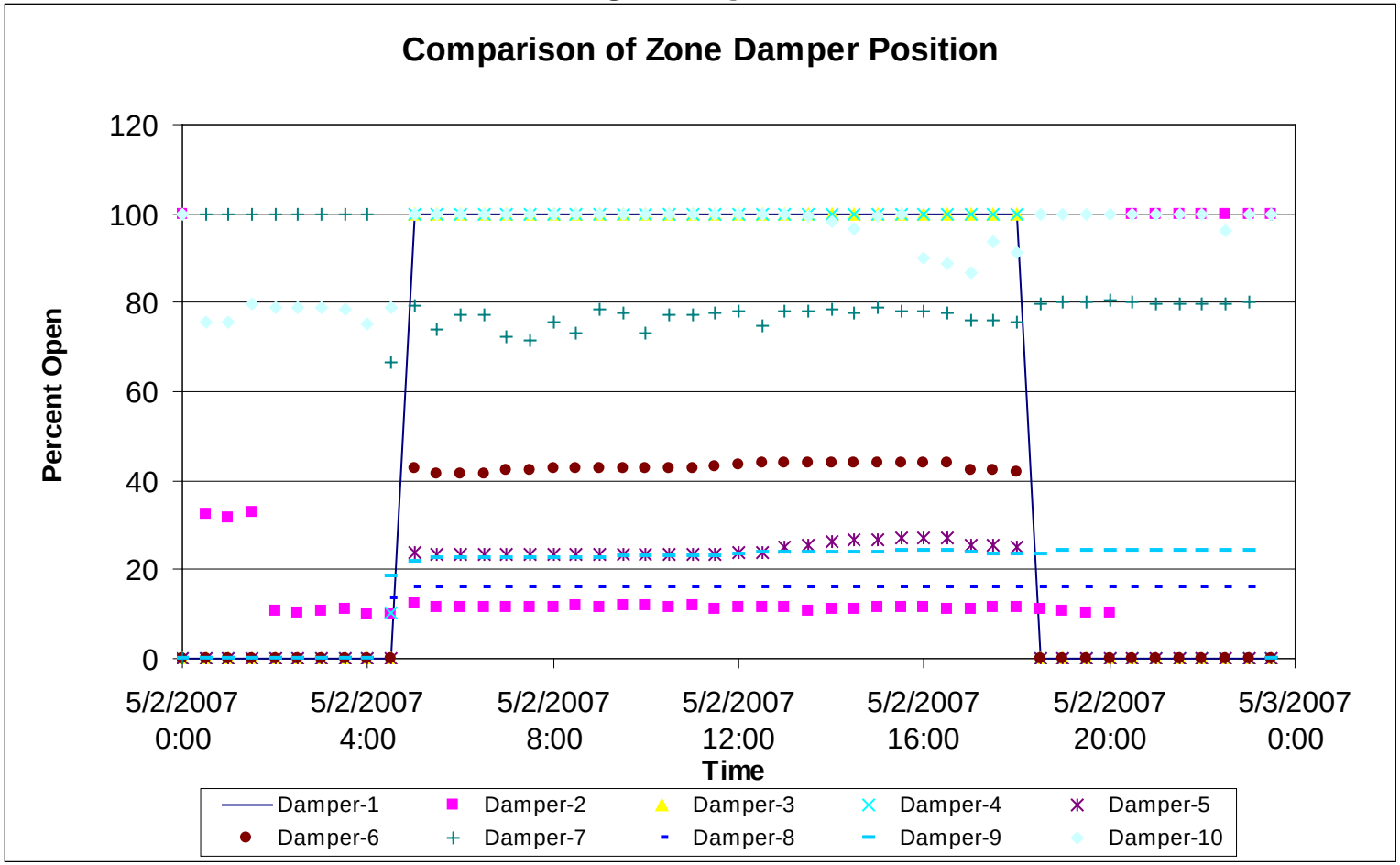
Zone Heating and Cooling Demands: Example of Good Operations

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: Example of Marginal Operation

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



Zone Heating and Cooling Demands: Example of Bad Operation

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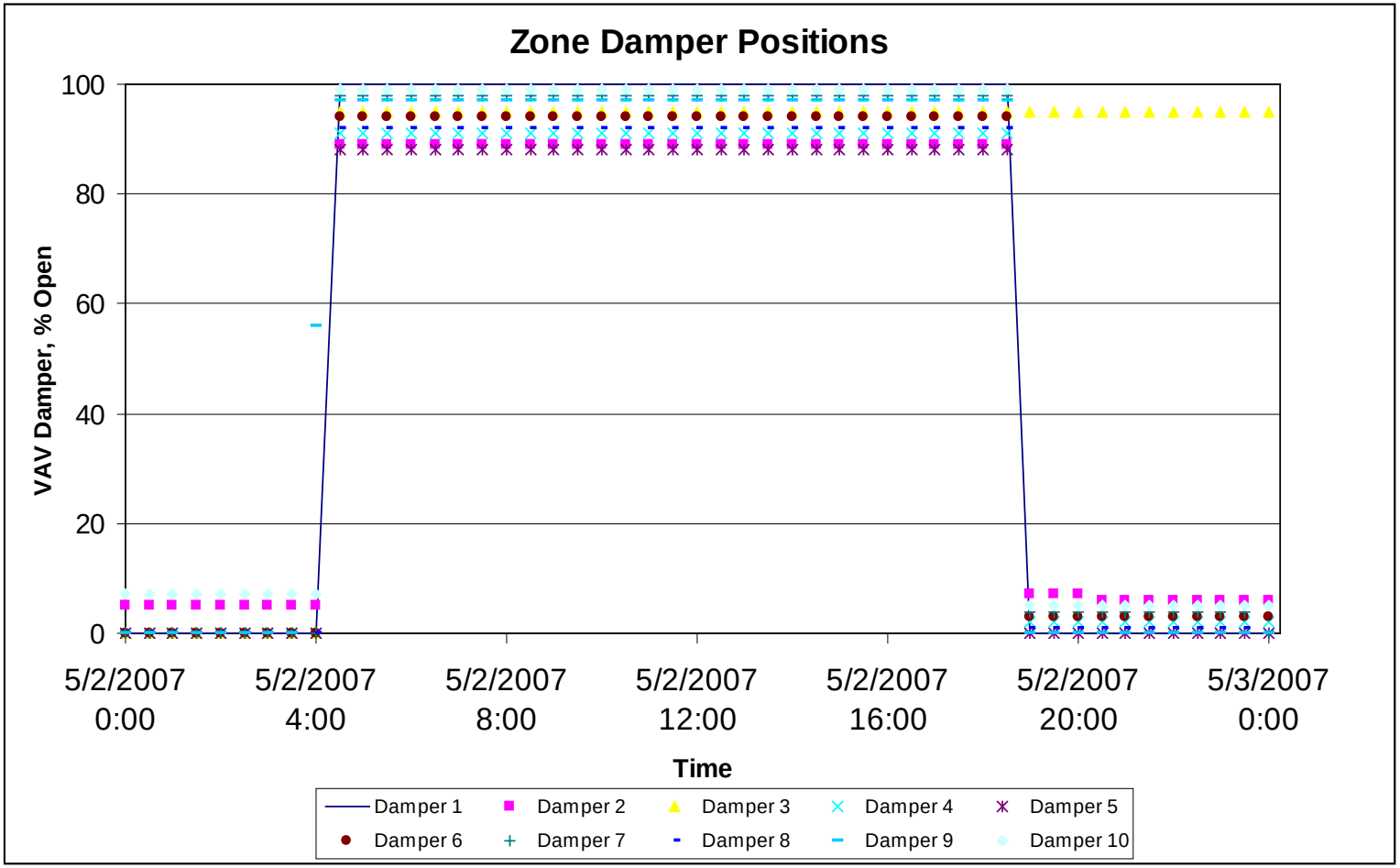
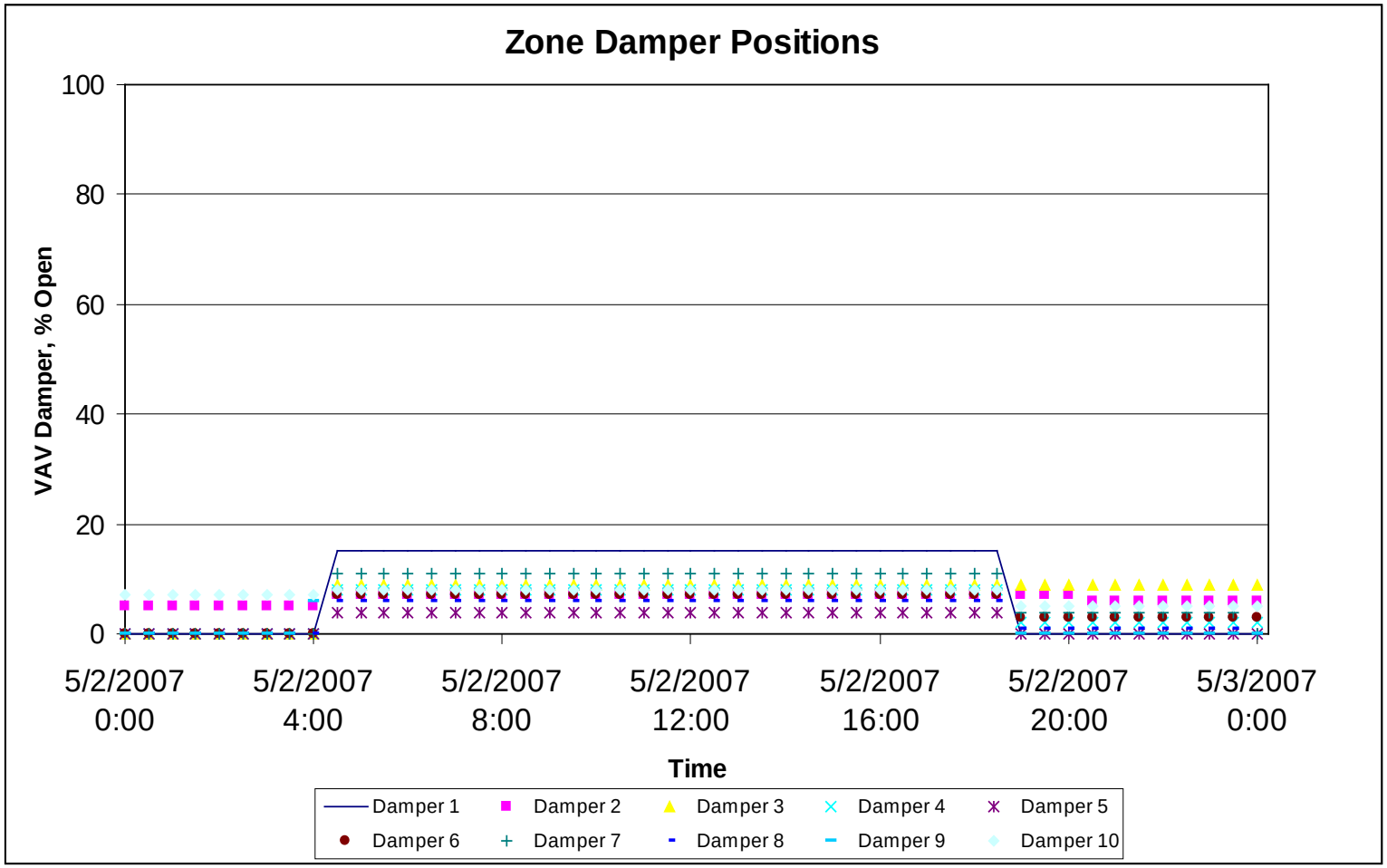
Plot of VAV unit dampers vs. time for all VAV units served by an air handler – **Bad Distribution – Too many near fully open**



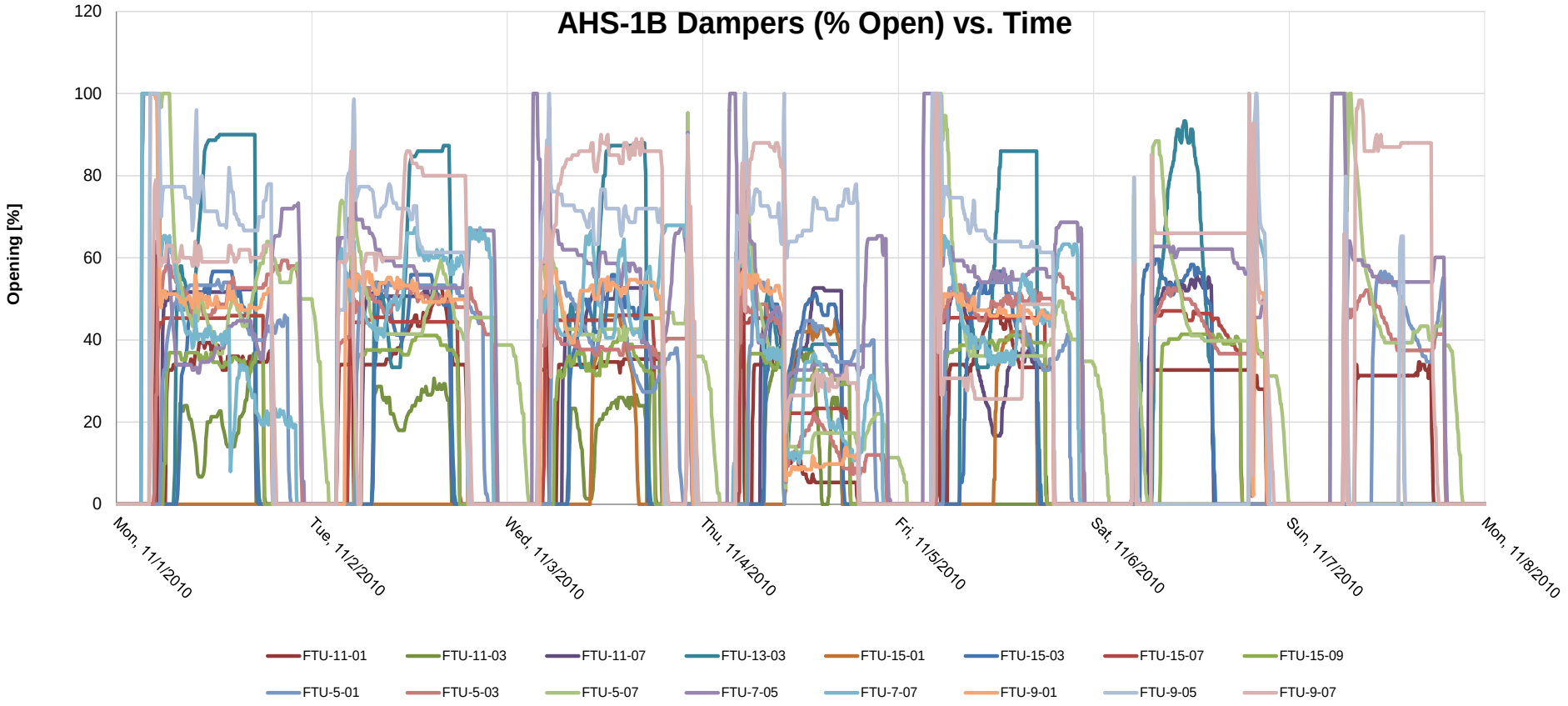
Zone Heating and Cooling Demands: Example of Bad Operation

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



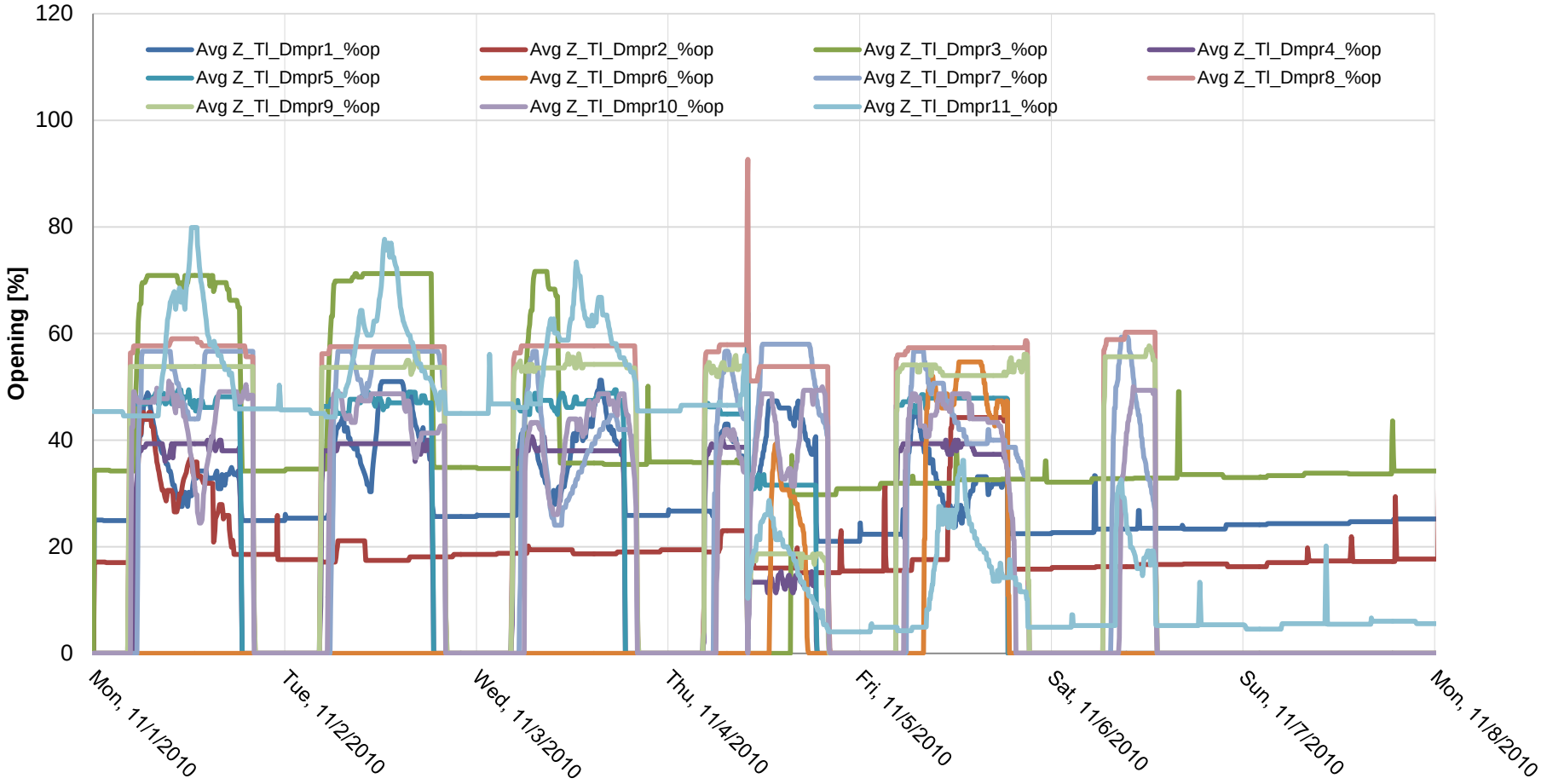
Zone: Another Example of Good Operation

- Good distribution (30%~90% most of time)



Zone: Another Example of Bad Operation

- Bad distribution (less than 60% most of time)

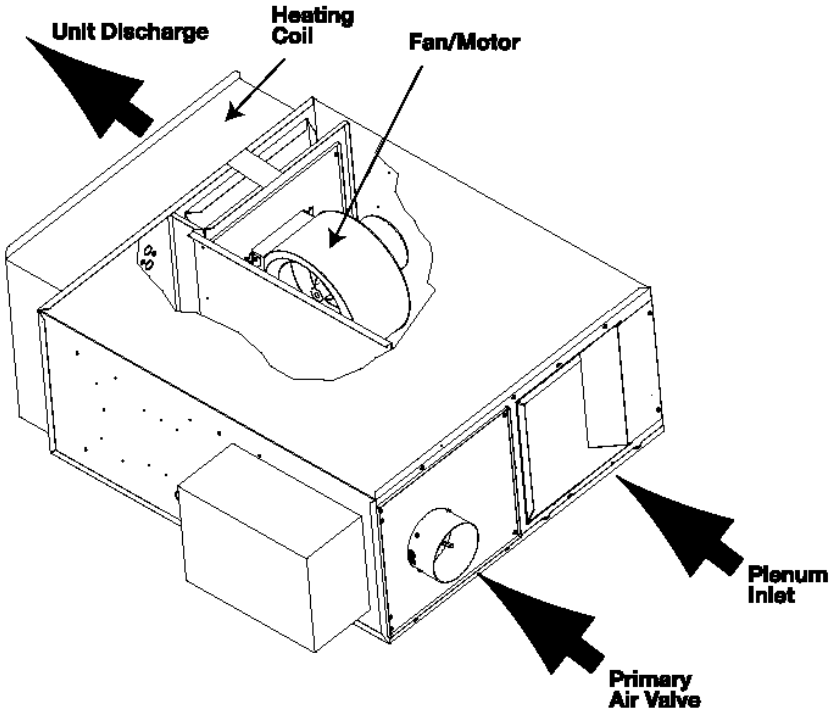


Fan Powered Box (FPB) Trend Data Collection and Analysis

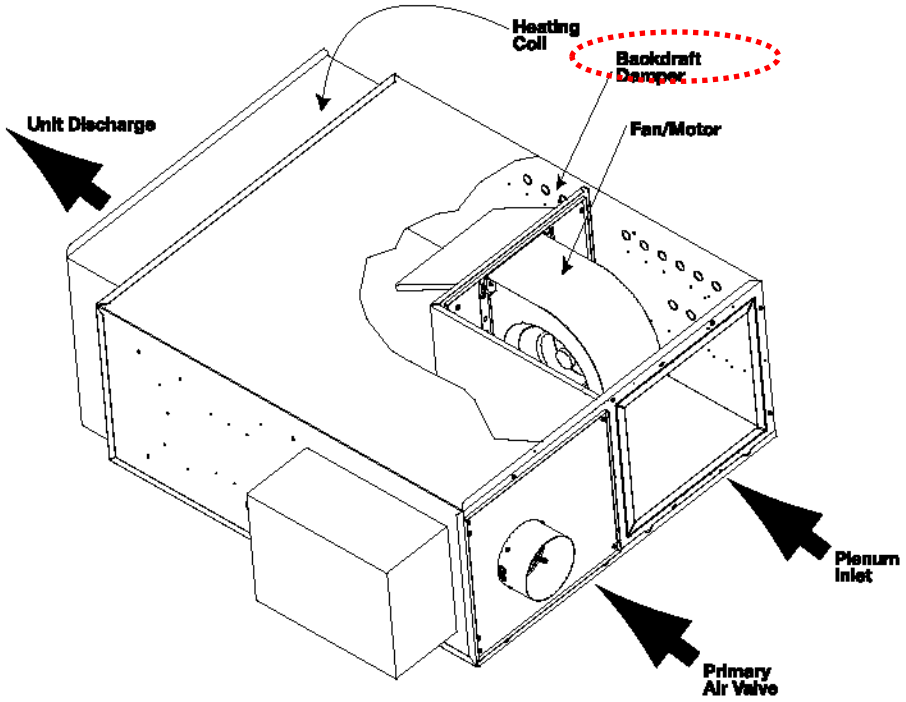
- Selecting zones for trending
  - Best approach: trend all zones operation if possible
  - If there's bandwidth constraints of data trending, you may select
    - Zones that are exposed to different orientation and zones that serve different needs or
    - Zones with thermal comfort issues
    - Zones with operation and maintenance issues
- Refer to the zone/VAV box monitoring plan

Series and Parallel FPB

- Series type (constant volume)
- Fan in series with primary air, runs continuously



- Parallel type (variable volume)
- Fan in parallel with primary air, runs only when needed



Source: Figures from Titus

FPB Parameters to Trend

- Trend as many of the following parameters as possible
  - Air-handling discharge-air temperature (ASAT)
  - Zone discharge-air temperature (ZDAT) after the FPB
  - Zone-air temperature and set point
  - Terminal fan motor (in FPB) on/off status
  - Damper position
  - Zone occupancy mode

FPB Data Analysis

- Key conditions to look for in the charts generated by the spreadsheet
  - Is the FPB fan ON at unoccupied hour
  - Significant mixing of return and primary air during summer/cooling season
  - Simultaneous heating and cooling

Possible Reasons for 24/7 FPB Fan Operation

- Issue: Unoccupied hour set back is not defined or enabled
- Purpose:
  - Determine whether the FPB fans follow the same schedule as the AHU provides the primary air
  - Determine whether the FPB fans are operated during unoccupied hours
- Approach:
  - Review plots of FPB fan status vs. time
  - Look for the fan status at unoccupied hour and determine the FPB operation schedule

Possible Reasons for Significant Reheat for Interior Zone

- Issue: There is significant reheat or mixing for interior zone FPB
- Purpose:
  - Determine whether the minimum air flow setting (primary air) is too high
- Approach:
  - Review the plots of air-handling unit discharge-air temperature (ASAT) and discharge-air temperature (ZDAT) after mixing/reheat vs. time
  - Look for the temperature difference between and after mixing

Re-Tuning Recommendations for FPB

- Define and enable the unoccupied set back control if possible
- Interlock the terminal fan with the AHU control
- Reduce the box primary minimum air flow setting based on ventilation requirements
  - Make sure at least 75 cfm/person for example

Re-Tuning Recommendations for FPB (continued)

- For multi-speed terminal fan
  - Switch fan to low speed during summer/cooling season
  - Operate terminal fan at low speed for interior zone FPB all the time
- For constant speed terminal fan
  - Shut off terminal fan during summer/cooling season to save the fan power when there is no need for heating or recirculation
  - Close heating coil valve during summer/cooling season to minimize simultaneous heating and cooling

Re-tuning FPB Boxes Benefits: Example

- Minimize simultaneous heating/cooling during summer
- Reduce fan power (for FPB) consumption during summer and unoccupied hours
- Improve thermal comfort, for some facilities
- Reduce the noise level significantly by shutting off the terminal fan when it is not needed

QUESTIONS?

www.pnnl.gov/buildingretuning