Large Commercial Buildings: Re-tuning for Efficiency

Air Handling Units: Pre-Re-Tuning and Trending and Re-Tuning
Air-Handler Data Analysis

Pre-Re-Tuning Phase:
Air-Handling Units: Trend-data collection and analysis

Re-tuning Phase:
Air-Handling Units: Occupied and Unoccupied Schedule
Air-Handler Data Analysis

Key conditions to look for while analyzing the charts:

- Is there any unoccupied operation or 24/7 operation
- Is there a set back during unoccupied period
- Lower/higher than expected discharge-air temperature
- Excessive outdoor-air intake
  - During occupied periods
  - During pre-heating/pre-cooling periods
- Significant reheat during summer/cooling season
- Is the supply fan modulating (if VAV)
- Higher than normal static pressure
- Set point and static pressure resets
- Economizer is not utilized or not working properly
Enable unoccupied mode and night set back control

Shut off units at night and weekend

Turn off heating systems (for reheat only) during summer

- When reheat system is shut off, room comfort may be maintained by increasing supply-air temperature – for constant volume units
- Do not turn heating off too early in the summer to avoid having to turn the system on and off repeatedly

Turn off systems during unoccupied hours

Slow down systems during unoccupied/lightly and occupied hours
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 before occupancy, for flushing building
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 systems running, fresh at full design conditions and all lights on
- Is this required?
During unoccupied and lightly-occupied periods, run fan static pressure at $\frac{1}{2}$ 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 (typically on the perimeter) 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
  - If set backs are active on all HVAC systems
  - Base load versus peak loads should be at least 50% difference and as much as 70% with aggressive set backs

- Trended data for zone temps should show 5-10°F deviations from occupied period set points when set backs are active during non-shoulder months
  - Winter zone temperatures should drop to 60-65°F and summer zone temperatures should rise to 80-85°F
Trended data for discharge static pressures should show readings of 0 in. or at least 50% (half) of normal (occupied) static pressure readings.

If static pressure trend is not available, trended data for main supply/return fan status should indicate “OFF” during unoccupied periods.

Trended data for VAV boxes “occupied/unoccupied” 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.
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 set backs

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, Outlook 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/stop” scheduling capability?
  - Are you using it?
Night and Weekend Temperature Set back and Supply-Fan Cycling

Purpose:
- Determine whether night and weekend temperature set back is being used effectively
- Check for unusually frequent supply-fan cycling

Approach:
- For each monitored air-handler, plot supply fan status vs. time
- Look for off status during scheduled off times, for the served zones to be unoccupied (nights and weekends)

Potential issues to identify
- No night set back for heating or cooling
- No weekend set back for heating and cooling
- Excessive supply fan cycling
Duct static pressure can be used to identify the system operation

**Bad Operation**

**Good Operation**
Night and Weekend Temperature Set back and Supply-Fan Cycling (continued): Bad Example

- Supply fan status vs. time – AHU runs 24/7 (Example of bad operation)

- Supply fan status vs. time – Possibly OK but no weekend set back
Supply fan status vs. time – Better – Longer night set back and weekend set back
Checking Schedule with Supply Fan Static Pressure

Example of Good Operation

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Checking Schedule with Supply Fan Static Pressure

Example of Good Operation

Chapter 5
Checking Schedule with Supply Fan Static Pressure

Opportunities?
Air-Handler Data Analysis

► Pre-Re-Tuning Phase:
  ■ Air-Handling Units: Trend-data collection and analysis of discharge-air temperature

► Re-tuning Phase:
  ■ Air-Handling Units: Discharge-air temperature set point
Air-Handler Data Analysis: Discharge-Air Temperature Set Point

**Purpose**
- Review discharge-air temperatures for the air-handlers
- Determine whether discharge-air temperatures are maintained relatively stable
- Determine whether the discharge-air temperatures are too cool or too warm

**Approach**
- For each air handler monitored, review plots of discharge-air temperature and discharge-air temperature set point vs. time and discharge-air temperature vs. discharge-air temperature set point
- Look for deviations between discharge-air temperatures and set points
- Look for unusually high (>70°F) or low (<55°F) discharge-air temperatures
Potential issues to identify

- Discharge-air temperature not meeting discharge-air temperature set point
- Unusually unsteady discharge-air temperatures
- Reset not being used for discharge-air temperature set point
- Discharge-air temperature set point too high or too low
One of the most important variables in a HVAC system:

- Low discharge-air temperature will cause:
  - Overcooling
  - Reheating in cooler zones
  - Portable heaters in offices
  - Drafts and cold complaints
  - Extra load on the cooling plant
  - Excess discharge-air pressure
  - Excess energy in reheating the overcooled zones
Discharge-Air Temperature Control (continued)

- Discharge-air temperature needs to be set low enough to handle the peak cooling load
  - Summer weather peak
  - Interior load peak
  - Staffing peak
  - Maybe 1% to 2% of the operating hours are at this condition, yet most systems run 100% of the time at this set point

- Reheat makes up for all areas that are too cold from a lower than needed discharge-air temperature
Discharge-air temperature can run as high as possible and still meet the cooling needs:

- VAV boxes can run at higher air flows
- Return-air can be warmer and help heat building
- Reheats will run a lot less
- Staff complaints go down due to less cold drafts
- Building is ventilated better

Reheat has to make up for all areas that are too cold from a lower than needed discharge-air temperature.
Discharge-Air Temperature Control (continued)

What is driving the current discharge-air temperature set point? Why is it set where it is?

- Engineered setting per drawings before building was built
- Field engineer
- Building/facility manager
- Technician best guess
- Current weather conditions
- Loudest customer complaint
- Because that is where it's always been, so it must be right
- ????????? ENERGY COST ????????
Discharge-Air Temperature Control (continued)

- Does the discharge-air set point vary with some input signals? > 55°F – < 70°F
- Set up a discharge-air temperature set point reset schedule based on the personality of the zones it feeds
- Examples:
  - Warmest 3 zones averaged
    - For example reset, if average zone temperature is 76°F, then discharge-air temperature should be 55°F
    - If average zone temperature is 72°F, discharge-air temperature can be as high as 65°F
  - Number of reheats running
    - 10 out of 15 zones in heat, then the discharge-air temperature can be as high as 70°F
    - 2 out of 15 zones in heat, then discharge-air can be as low as 55°F
  - Coolest perimeter zone
  - Outdoor-air temperature
    - If outdoor-air temperature is 50°F, then the discharge-air is 70°F
    - If outdoor-air temperature is 75°F, then the discharge-air is 55°F
Discharge-Air Temperature Control
(continued)

- Occupant complaints (if many) could be a precursor to an improperly working (or non-functioning) discharge-air temperature control scheme.

- Trended data for discharge-air temperatures that is “flat” or rarely varies is a strong indicator of a non-functioning discharge-air temperature “reset” control.

- Trended data for discharge-air temperatures that show sharply falling temperatures well below set point that are coincidental to the chiller system starting and remain well below set point are indicative of a failed (leaking) cooling control valve.

- Trended data for discharge-air temperatures that show sharply rising temperatures well above set point that are coincidental to the boiler/reheat system starting and remain well above set point are indicative of a failed (leaking) heating control valve.
Discharge-Air Temperature Control

- Trended data for discharge-air temperature “reset” control that is working should show temperature set points that vary as the building “wakes up” in the morning hours and then changes as the building becomes occupied and continues to change during the late morning and early afternoon hours and continues to see changes due to changing outdoor ambient temperatures and solar loading. This can vary as much as 10 to 15°F over the course of the day.

- Does your DDC system already calculate: warmest zone temperature, lowest zone temperature, average zone temperature?
  - If not, then it is doubtful that your DDC is set up to reset the discharge-air temperature set point based upon a feedback that reflects true building load conditions.

- Does your DDC system currently reset the discharge-air temperature set point using either outside-air temperature or return-air temperature?

- Preferred order to reset discharge-air temperature is from zone conditions, return-air temperature and then outside-air temperature.
Discharge-Air Temperature Control

- **Summer mode (for example, outdoor-air temperature >75°F):**
  - Set discharge-air temperature set point at 55°F
  - Shut off heating coil valve

- **Winter mode (for example, outdoor-air temperature <60°F):**
  - Set discharge-air temperature set point at 65°F, if less than 40% of zones require cooling
  - If more zones call for cooling than heating, discharge-air temperature set point can be lowered to 55°F
  - Shut off the cooling coil valve, if the freeze protection is not enabled

- Heating and cooling valves can be closed when outdoor-air temperature is in between summer mode and winter mode
Air-Handler Discharge-Air Temperatures: Example use of Graphs

- Discharge-air temperature and discharge-air temperature set point vs. time – 3 days

![Discharge/Discharge Set Point Temperature vs. Time](image-url)

Example of Good Reset Operation
Air-handler Discharge-Air Temperatures: Example use of Graphs

- Discharge-air temperature and discharge-air temperature set point vs. time – 3 days

Example of Bad Operation - No Reset (Constant day and night)
Air-handler Discharge-Air Temperatures: Example use of Graphs

- Opportunity to decrease the discharge-air temperature (total VAV terminal box number is 279)

**VAV's # in Cooling and Heating Mode, OAT vs. Time**

Example use of Graphs

Opportunity to decrease the discharge-air temperature (total VAV terminal box number is 279)

Example of Bad Operation - No Reset

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Air-Handler Discharge-Air Temperatures: Example use of Graphs

- Opportunity to increase the discharge-air temperature when outdoor-air temperature (OAT) is lower than 50°F (total VAV terminal box number is 108)

**VAV's # in Cooling and Heating Mode, OAT vs. Time**

Example of Bad Operation - No Reset
Discharge-Air Temperature Control

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Discharge-Air Temperature Control

Chapter 5
Air-Handler Data Analysis: Static Pressure

► Pre-Re-Tuning Phase:
  ■ Air-Handling Units: Trend-data collection and analysis for duct static pressure

► Re-tuning Phase:
  ■ Air-Handling Units: Duct static pressure
Air-Handler Data Analysis: Static Pressure

Purpose: Determine whether the static pressure set point is too high or too low or if static pressure is changing over time

Approach:
- For each air handler, review a plot of the damper positions of all VAV units vs. time
- Look for situations where:
  - Most dampers are nearly closed during cooling – static pressure too high
  - Several VAV boxes on an air handler have dampers fully open – static pressure is too low and VAV boxes are not able to meet zone loads – starved boxes
  - Dampers are not modulating as conditions change – VAV boxes that are not being controlled or not responding to control signals
Static Pressure Control

Does the static pressure vary with some input signals?

- Like discharge-air temperature, static pressure should follow the real load conditions
  - Too high and VAV boxes have trouble controlling
  - High noise levels in ceiling or at diffusers coming from VAV box
  - Extra load on air handler not required
    - Higher CFMs
    - More chiller load
    - More fan wear and belt wear
    - Higher fan energy cost. **horsepower** varies with the **CUBE** of the **speed**

- Ideally, VAV dampers should run in the 50% to 75% range (non-design conditions)
Static Pressure Control

- Static pressure control specifications taken directly from a vendor’s standard specifications
- VAV control
  - **STATIC PRESSURE CONTROL:** THE SUPPLY FAN WILL MODULATE TO MAINTAIN THE DISCHARGE STATIC PRESSURE SET POINT
    - Who determines set point? Normally a computer before the building is ever built!
- Control contractors are not actively coding in intelligent control functions unless an engineer asks for it
- Engineers are designing to basic design conditions and are not concerned about system control in shoulder conditions
Static Pressure Control (continued)

- Use a reset schedule based on damper position
  - Read all damper positions
  - Sort by descending position, highest to lowest
  - Reset discharge static to maintain the average of the 3\textsuperscript{rd} highest to the 7\textsuperscript{th} highest positions to about 75\% open
    - Do not use failed dampers or outliers in calculations

- Main idea is match control point to actual need

- Example would be systems that run at 0.5 in. in the morning and 2 in. in the afternoon when fully loaded
Example of cause and effect
Discharge pressure transmitter failed
  - Fan failed at full speed
Building owner determined not to fix it because tenants did not complaint
Utility bill went up several thousands of dollars over a 1-year period
  - Utility bill is passed on to tenant
Tenant finally complained about increase and then helped owner determine cause
Owner did the $100 repair
The utility bill dropped thousands of dollars!
Occupant complaints (if many) could be a precursor to an improperly working discharge static pressure control scheme.

Excess static pressure can result in excess air and cold drafts as well as high noise levels in office spaces from diffuser noise.

Excess supply fan static pressure can result in outside-air being “drawn” into the mixing box plenum section, via the exhaust damper.

If this is observed in field walk-downs, verify that the return fan is operating correctly; otherwise, excess supply static pressure should be one suspect.
Static Pressure Control (continued)

- Trended data for static pressure control that is working should show static pressure varying
  - Set points that vary as the building “wakes up” in the morning hours and then changes as the building becomes occupied and continues to change during the late morning and early afternoon hours and continues to see changes due to changing outdoor ambient temperatures, solar loading and internal gains

- If the static pressure control is constant, then the fan speed (load) should vary as noted above
Static Pressure Reset Based on Terminal Box: Example of Good Operation

Static Pressure before re-tuning and After re-tuning

Before re-tuning ↔ After re-tuning

Example for Bad and Good Operation
Static Pressure Reset Based on Terminal Box: Example of Good Operation

Static Pressure Reset (lightly occupied building at night)

Example of Good Operation

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No Static Pressure Reset: Example of Bad Operation - Constant Day and Night

Duct static pressure and set point vs. time

Example of Bad Operation - No Reset
No Static Pressure Reset: Example of Bad Operation

Duct static pressure and set point, and outdoor-air temperature vs. time

Example of Bad Operation - No Reset
Air-Handler Data Analysis: Heating and Cooling

► Pre-Re-Tuning Phase:
  ■ Air-Handling Units: Trend-data collection and analysis of heating and cooling

► Re-tuning Phase:
  ■ Air-Handling Units: Heating and cooling
Are the heating and cooling coils efficient?

- Clean
- Valves not leaking through
  - Check (touch) coil for temperature of pipes at air-handler penetrations
    - Should be room temperature, if not active
- Loops locked out at some outdoor-air temperature preventing heating and cooling at same time
  - Heating locked out above 50°F or lowest temperature building can do without heat
  - Cooling locked out below 55°F or highest temperature building can do without cooling
  - Critical on dual-duct and multi-zone systems

Balance point of building is critical when setting these lockouts
Trended data for discharge-air temperatures that show sharply falling temperatures well below set point that are coincidental to the chiller system starting and remain well below set point are indicative of a failed (leaking) cooling control valve.

Trended data for discharge-air temperatures that show sharply rising temperatures well above set point that are coincidental to the boiler/reheat system starting and remain well above set point are indicative of a failed (leaking) heating control valve.

Trended data for discharge-air temperature that shows a heating valve open to maintain discharge-air set point with the economizer control on full re-circulation (or minimum outside air) and a mixed-air temperature that is above the discharge-air temperature, is indicative of a leaking chilled water valve (if the chiller system is active).

If condensate is observed on un-insulated lines or exposed coil sections during times when mechanical cooling is not being called for by the control system or during times when outside-air temperature should be adequate for “free” cooling, then leaking cooling control valves should be suspected.

If heating and cooling loops come with outside-air temperature lockouts, but those lockout settings are set to abnormal values, this would indicate failed or leaking control valves that indicate simultaneous heating and cooling (energy intensive).
Purpose: Determine whether the outdoor-air lockouts for heating and cooling are set to reasonable values

Approach:
- Use plots of heating and cooling set points vs. time to determine whether lockouts are set backwards – cooling lockout is lower than the heating lockout
- Use plots of heating and cooling valve positions to determine whether heating and cooling of the air stream are taking place at the same time
Potential issues to identify

- Air-handler heating and cooling coils operating simultaneously
- Heating and cooling lockouts possibly overlapping (need to be confirmed in control-code settings during on-site re-tuning)
- Unreasonable values are set for the heating and cooling lockouts
Outdoor-Air Lockouts for Heating and Cooling: Example use of Graphs

- Air-handler heating vs. cooling valve positions

![Graph: Chilled Water vs Hot Water Valve Signals](image)

- Worse
- Bad
Lockout for Cooling During Winter Season: Before and after Building Re-tuning

- Heating coil valves and cooling coil valve signals vs. time

**Example of Bad Operation**

**Example of Good Operation**
Example of Simultaneous Heating and Cooling: Bad Operation

- Heating and cooling coil valve signal vs. time

Example of Bad Operation

Chilled Water Valve Signal

Hot Water Valve Signal

Example of Simultaneous Heating and Cooling: Bad Operation
Example of Simultaneous Heating and Cooling: Bad Operation

Heating and cooling coil valve signal, and outdoor-air temperature vs. time

Example of Bad Operation

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Example of Simultaneous Heating and Cooling: Bad Operation

- Heating and cooling coil valve signals, and outdoor-air temperature vs. time

Example of Bad Operation

- Outdoor-Air Temperature
- Chilled Water Valve Signal
- Hot Water Valve Signal

Chapter 5
Pre-Re-Tuning Phase:
- Air-Handling Units: Trend-data collection and analysis of minimum outdoor air

Re-tuning Phase:
- Air-Handling Units: Minimum outdoor air operations
Air-Handling Unit: Minimum Outdoor-Air Operations

Purpose

- Review minimum outdoor-air operations
- Determine whether sufficient outdoor-air is being supplied for ventilation
- Determine whether more outdoor-air than needed is being brought in at times (e.g., when the outdoor-air temperature < 40°F or > 60°F or when the zones served are unoccupied)
- Determine whether outdoor-air dampers close during night and weekend set back and during startup mode in the morning
Air-Handling Unit: Minimum Outdoor-Air Operations (continued)

Approach

- For each air-handling unit with air-side economizer, review plots:
  - Outdoor-air fraction (OAF) vs. time
  - Outdoor-air damper and occupancy mode vs. time
  - Outdoor-air fraction vs. fan speed (if available)

- Determine if OAF > minimum OAF for ventilation when the system is not economizing

- Determine whether outdoor-air ventilation is being provided when the building is unoccupied and ventilation is not required for some other reason, especially when in the heating mode and when conditions are not favorable of economizing in cooling mode

- If OAF and fan speed are tracking each other, it is an indication of return-air problems

- 20% damper position is never 20% outdoor air
Potential issues to identify

- Insufficient outdoor-air ventilation provided – minimum outdoor-air fraction (OAF) is too low
- Too much outdoor-air ventilation provided when the air-handler is not economizing
- Too much outdoor-air ventilation provided during unoccupied times (nights and weekends, during set back)

Use air fraction to find % of outdoor-air

- Works if air is mixed relatively evenly
- \[ \text{OAF} = \frac{(\text{Return-Mixed})}{(\text{Return-Outdoor})} \times 100 \]
- Add into code for all air handlers and track history
  - Especially schools and other public spaces

Use CO₂ sensors whenever possible for areas with changing staff loads and larger spaces (conference rooms, auditoriums, etc)

- Infiltration may satisfy ventilation needs without outdoor-air dampers being open
Does your DDC system have separate outdoor-, return- and mixed-air temperature sensors?

Does your DDC system use these values to calculate outdoor-air fractions?
20% damper is never 20% air flow

Pressure differential across outdoor-air damper is more important than damper position

No pressure differential leads to no flow

High delta leads to high flow
Outdoor-air fraction and temperature, and damper position vs. time: building occupied 24/7
Outdoor-air fraction and temperature, and damper position vs. time: building occupied 12 h/d
Air-Handling Unit: Minimum Outdoor-Air Operations: Normal Operation

➤ Outdoor-air damper vs. time

Minimum Outdoor-Air Damper Position = 15%

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Air-Handling Unit: High Minimum Outdoor-Air Damper Position

- Outdoor-air damper vs. time

High Minimum Outdoor-Air Damper Position = 30%

Chapter 5
QUESTIONS?

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