Large Commercial Buildings: Re-tuning for Efficiency

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

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

Example of Bad Operation

Example of Good Operation
Zone Data Analysis: No Night Time Set Back?

Chapter 7
Zone Data Analysis: Fan Powered Box

![Graph showing Zone Data Analysis](image)

- **Avg Z_Tl_Dmpr6_%op**
- **Avg Z_Tl6_Rht%**
- **Avg Z6_Temp**

Mon, 3/28/2011
Tue, 3/29/2011
Wed, 3/30/2011
Thu, 3/31/2011

**Opening [%], Reheat [%], Temperature**
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°F, for example) to eliminate the heating leakage
  - It can be accomplished by the terminal box control programming or building heating system control
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
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°F
Example of Simultaneous Heating and Cooling for Exterior Zone Terminal Boxes

- **OAT>72°F, reheat is still on**

Example of Bad Operation

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

![AHS-1B Dampers (% Open) vs. Time](image_url)
Zone: Another Example of Bad Operation

Bad distribution (less than 60% most of time)

![Graph showing bad distribution with opening percentages over 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?
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