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Instructor Manual: Re-tuning Large Commercial Buildings

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Summary

Commercial buildings account for almost 20% of the total U.S. energy consumption[1], and 10% to 30% of the energy used in commercial buildings is wasted because of improper and inefficient operations[2]. While sophisticated energy management and control systems are used in large commercial buildings to manage heating, ventilating, and air conditioning systems and components, many buildings still are not properly commissioned, operated, or maintained. This lack of proper operation and maintenance leads to inefficiencies, reduced lifetime of equipment, and, ultimately, higher energy costs.

The U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL) has developed a building re-tuning process to detect energy savings opportunities and implement improvements. Re-tuning is a systematic process to identify operational problems by leveraging data collected from the building automation system (BAS) and correcting those problems at no-cost or low-cost. Over the past 5 years, PNNL has provided building re-tuning classroom instruction and field training to more than 300 building operators, engineers, and energy managers from more than 30 organizations. To reach a larger audience more quickly, PNNL has developed this train-the-trainer instructor manual, to help qualify more re-tuning course trainers.

Purpose of Building Re-tuning Training Course

The purpose of this course is to help building operations staff to learn how to operate buildings more efficiently, reduce operating cost and provide energy savings. The knowledge and skills learned through the training will be highly valued by organizations and companies seeking to improve the performance of their buildings.

Intended Audience for Building Re-tuning Course

The intended audience for the building re-tuning training includes:

- onsite employees responsible for day-to-day building operations,
- offsite contractors (retro-commissioning agents or control vendors) hired to improve a building's energy efficiency, and
- people interested in entering this field, including college students and military veterans.

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[1] See the U.S. Department of Energy's *Buildings Energy Data Book*, Table 1.1.3, http://buildingsdatabook.eren.doe.gov/default.aspx

[2] Claridge, D.E., M. Liu, Y. Zhu, M. Abbas, A. Athar, and J.S. Haberl. 1996. "Implementation of Continuous Commissioning in the Texas LoanSTAR Program: Can You Achieve 150% Estimated Retrofit Savings Revisited." In Proceedings of the 1996 ACEEE Summer Study on Energy Efficiency in Buildings. ACEEE, Washington, DC.

Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M.A. Piette. 2004. The Cost-Effectiveness of Commercial-Buildings Commissioning: A Meta-Analysis of Energy and Non-Energy Impacts in Existing Buildings and New Construction in the United States. LBNL 56637. Berkeley, California: Lawrence Berkeley National Laboratory.

The focus is on large (100,000 sq. ft.) commercial buildings (office buildings, malls, and schools) with building automation systems (BAS), but the concepts and techniques presented can be applied to any type and size of facility that has a BAS.

Intended Audience for the Building Re-tuning Instructors Manual

The primary audience for this instructor manual is the person who will be teaching the re-tuning course. In addition, community college instructors, retro-commissioning training providers and building operator training providers may find value in the material presented in this instructor manual as well.

Method of Instruction

The method of instruction is through classroom lecture and discussion, followed by hands-on in-the-field training.

Lesson Goals and Objectives

The lesson goals and associated objectives for each lesson are given at the beginning of the lesson chapter and are summarized below:

1. Chapter 1: Understand the purpose of re-tuning, definition of building re-tuning and what to expect from the re-tuning training class
2. Chapter 2: Understand that re-tuning is the process of learning a building and then making incremental adjustments to achieve more desirable results:
    a. Learn through examples that re-tuning works
    b. Understand the importance of learning a building's "personality"
    c. Understand that it takes time to learn a building's personality
3. Chapter 3: Understand the information needed:
    a. Purpose of collecting initial building information
    b. Kinds of information needed
4. Chapter 4: Understand how to use the Energy Charting and Metrics tool:
    a. Purpose of trend data collection and analysis
    b. Develop monitoring plans
    c. Understand how to interpret trend graphs
5. Chapter 5: Learn how to re-tune air-handling units (AHUs):
    a. Collect basic information for AHUs

    b. Understand the points needed for trend graph analysis for AHUs
    c. Develop monitoring/trending plan for AHUs
    d. Generate AHU trend graphs
    e. Analyze AHU trend graphs and identify opportunities for improvement
    f. Re-tune the AHUs
6. Chapter 6: Understand economizer operations:
    a. Understand basic economizer operations
    b. Understand the points to plot for economizers
    c. Generating economizer trend graphs
    d. Analyzing economizer trend graphs
    e. Re-tuning the economizer
7. Chapter 7: Understand terminal units:
    a. Understand basic terminal unit operations
    b. Understand the points to plot for terminal units
    c. Generate zone trend graphs
    d. Analyze zone trend graphs
    e. Re-tune the terminal units
8. Chapter 8: Understand central plants:
    a. Understand the point to plot for the central plant
    b. Generate central plant trend graphs
    c. Analyze center plant trend graphs
    d. Re-tune the central plants
9. Chapter 9: Conduct a thorough building "walk down":
    a. Know what to look for in mechanical and electrical prints
    b. Know what to look for on and in the building's exterior, interior, roof, and plant area
    c. Know how to use the building automation system to complete the walk down

10. Chapter 10: Re-tune the building based on specific findings:

    a. Understand that certain problems (no night/weekend set back, overridden schedules) can and should be corrected

    b. Understand that most re-tuning actions should be conservative (small changes over time) – there are no magic set points, and every building is different

Building Re-tuning Resources

The building re-tuning project website has a number of useful resources and links to other resources from which instructors and students can benefit. The project website's URL www.pnnl.gov/buildingretuning includes the following re-tuning resources:

- the most up-to-date instructor's manual,
- training handouts,
- a complete deck of PowerPoint slides included in the training,
- *Energy Charting and Metrics (ECAM) User Guide* and tool,
- other building re-tuning resources, including links to relevant websites.

How to Use This Guide

Each page in the main portion of the guide is a boxed representation of a training slide. Below the representation are notes to the instructor and talking points to help the instructors speak to the slide. Instructors should thoroughly familiarize themselves with this guide, the slides, and the *ECAM User Guide* before teaching the course. Instructors are encouraged to customize the slides for their specific purposes. To maximize the potential of this material, it is expected that the instructor will be teaching by using a *specific* building as an example, and that the day after the classroom training, the instructor and students will conduct a field visit and begin to re-tune the building. Therefore, in some instances instructors will need to create customized slides, especially in the final re-tuning lesson.

Contents

Chapter 1: Introduction

INSTRUCTOR GUIDANCE

TIME: 20 MINUTES

MATERIALS: POWERPOINT SLIDES 01 INTRODUCTION TO CLASS

LESSON GOAL: UNDERSTAND THE PURPOSE OF THE CLASS

LEARNING OBJECTIVES:

- DESCRIBE THE PURPOSE OF BUILDING RE-TUNING
- DEFINE RE-TUNING

Purpose of Class

- Provide an in-depth overview of the Re-Tuning Method
- Prepare for hands-on field training on one of your buildings
- Provide an opportunity to ask questions and get clarification on any aspect of the re-tuning process

01 Introduction to Class, Slide 2

Instructor Notes

- The Pacific Northwest National Laboratory has developed a methodology for making commercial buildings more energy efficient. The PNNL staff members who developed this method and training are 1) scientists and engineers with many years of experience developing and testing new technologies and approaches to improve the efficiency of commercial buildings and 2) staff with years of experience operating, maintaining, and managing buildings and building systems as well as deploying energy efficiency programs in the field.
- It is up to the instructor whether to conduct the field training (building walk-down) portion of the course, but it is highly recommended.
- More background: Re-tuning training was originally developed as part of a project fund by Washington State (www.retuning.org). PNNL then extended training outreach beyond Washington State (www.pnl.gov/buildingreturning).

PURPOSE OF RE-TUNING

- IMPROVE THE BUILDING'S ENERGY EFFICIENCY THROUGH LOW-COST AND NO-COST OPERATIONAL IMPROVEMENTS
- IDENTIFY OPPORTUNITIES TO FURTHER INCREASE THE BUILDING'S ENERGY EFFICIENCY
- IDENTIFY PROBLEMS REQUIRING PHYSICAL REPAIR
- CATCH THE BIG ENERGY SAVING OPPORTUNITIES – OPERATIONS

01 INTRODUCTION TO CLASS, SLIDE 3

- Most of these low-cost/no-cost improvements are done by making adjustments to controls in the building automation system.
- Other low-cost improvements may be found in resetting bypassed systems (for example).
- You will want to identify broken or sick systems.
- The biggest energy savings are usually found in making operational changes, as you will see.

MAJOR FOCUS AREAS IN RE-TUNING

- OCCUPANCY SCHEDULING
- DISCHARGE AIR TEMPERATURE CONTROL
- DISCHARGE AIR STATIC PRESSURE CONTROL
- AIR HANDLING UNIT (AHU) HEATING AND COOLING
- AHU OUTSIDE/FRESH AIR MAKEUP
- AHU ECONOMIZER OPERATION
- ZONE CONDITIONING
- WHOLE BUILDING ENERGY END USE (ELECTRICITY AND GAS) DATA ANALYSIS
- CENTRAL PLANT

01 INTRODUCTION TO CLASS, SLIDE 4

- The basic idea behind occupancy scheduling is to shut off (or turn down) systems whenever occupants are not in the building or need less service from systems.
- Discharge-air temperature is the single most important variable in an HVAC system and is the most costly in terms of energy use.
- Discharge air static pressure control is the pressure that is maintained in the duct by the fan so that variable air volume units can provide proper air flow.
- There are many types of AHUs. This training focuses primarily on all-air systems. Instructors who want to focus on a different type will need to adjust the PowerPoint slides and this guide.
- Air-side economizing uses unconditioned outside air to cool or heat a space. Problems with the economizer usually occur when dampers are broken or malfunctioning or when cooling is operating when the economizer should be used. We will go into this in more depth Chapter 6: Economizer Operations: Pre-Re-Tuning and Re-Tuning.
- Zone set points drive the system and can have a ripple effect all the way to the meter. Also, one zone can drive multiple zones around it.
- The meter profile shows the heartbeat of the building. It reveals modes of operation, demand, time of use, occupied and unoccupied periods, and weekend events.
- Central plant equipment includes chillers, boilers, and cooling towers. How they are sequenced or staged has a big impact on energy consumption.

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
- May include 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 at a fraction of the cost

01 Introduction to Class, Slide 5

- This class will teach you the process so that you can improve your assigned building's energy efficiency.
- The only cost incurred through making changes to the building control system is labor to perform re-tuning.
- An example of low-cost repairs is replacing faulty sensors. Ask the class if they can think of others.
- Although not the focus of re-tuning, you might recommend replacing antiquated, poorly functioning major equipment with modern, energy-efficient systems.
- Other maintenance issues related to filters, coil cleaning, door seals, replacing missing insulation, repairing leaking control valves, etc. can also be discussed or identified as part of the re-tuning, again this is not the primary intent of re-tuning
- Re-tuning can be thought of as scaled-down retro-commissioning focused on identifying and correcting operational problems.

WHAT IS RE-TUNING?

- IF YOU DON'T NEED IT, TURN IT OFF.
- IF YOU DON'T NEED IT AT FULL POWER, TURN IT DOWN.

01 INTRODUCTION TO CLASS, SLIDE 6

- This is just basic energy management.
- Keep these concepts in mind through the entire re-tuning process.

FOUR PRIMARY STEPS OF RE-TUNING

- COLLECT INITIAL BUILDING INFORMATION
- PRE-RE-TUNING
- BUILDING WALKDOWN
- RE-TUNING

01 INTRODUCTION TO CLASS, SLIDE 7

- You'll gather basic information about the building such as approximate square feet, number of floors, building shape, approximate number of each major type of equipment, etc.
- In the pre-retuning phase, you'll collect trend data and analyze it.
- During the building walk-down, you'll get to know the building by examining its exterior, interior, roof, and plant area.
- In the re-tuning phase, you will correct operations problems.
- Two additional steps are possible: reporting re-tuning findings and conducting savings analysis.

INTERNET RESOURCES

- WWW.PNL.GOV/BUILDINGRETUNING
- WWW.RETUNING.ORG

01 INTRODUCTION TO CLASS, SLIDE 8

- The first one is the main project website.
- The second is a companion project site.

QUESTIONS?

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01 INTRODUCTION TO CLASS, SLIDE 9

- Ask the class if they have any questions.

Chapter 2: Building Personality

INSTRUCTOR GUIDANCE

TIME: 30 MINUTES

MATERIALS: POWERPOINT SLIDES 02 BUILDING PERSONALITY

LESSON GOAL: UNDERSTAND THAT RE-TUNING IS THE PROCESS OF LEARNING A BUILDING AND THEN MAKING INCREMENTAL ADJUSTMENTS TO ACHIEVE MORE DESIRABLE RESULTS

LEARNING OBJECTIVES:

- LEARN THROUGH EXAMPLES THAT RE-TUNING WORKS
- UNDERSTAND THE IMPORTANCE OF LEARNING YOUR BUILDING'S PERSONALITY
- UNDERSTAND THAT IT TAKES TIME TO LEARN YOUR BUILDING'S PERSONALITY.

TERMS RELATED TO RE-TUNING

- COMMISSIONING
- RETRO-COMMISSIONING
- RE-COMMISSIONING
- CONTINUOUS COMMISSIONING®

Continuous Commissioning is a registered trademark of the Texas Engineering Experiment Station Energy Systems Laboratory

02 BUILDING PERSONALITY, SLIDE 2

- Commissioning: Setting up control systems for new construction and major renovations.
- Retro-commissioning: Commissioning for an existing building that has never been commissioned.
- Re-commissioning: Commissioning for a building that has been commissioned before.
- Continuous Commissioning: A continuous practice of commissioning actions for persistent benefit.
- These terms all relate to the process of setting up control systems to some known design configurations, and the process of verifying set points and adding or modifying control algorithms. But how do we know what these set points and configurations are? Do we get them from engineers, buildings owners, or through "tribal knowledge" from service technicians? In most cases, we get them from a combination of the three.

RECENT RESULTS

- PNNL WAS HIRED TO RE-TUNE LARGE COMMERCIAL BUILDINGS
- COLLECTED AND ANALYZED INFORMATION
- MADE SMALL, INCREMENTAL CHANGES OVER TIME

02 BUILDING PERSONALITY, SLIDE 3

- The high-rise building was 1.8 million square feet and covered two city blocks. It was mostly glass on all sides. 10 MW feeder to the building. All electric, perimeter box reheat. Four chillers — three 1500-ton, one 500-ton. Variable chilled water flow. Paired variable air volume (VAV) air handler for each floor. True VAV facility. About 100 handlers total.

- PNNL staff collected trend graphs, mechanical prints, and other information to get to know the building before implementing any changes.

- After analyzing the collected information, the staff and building engineers began implementing incremental changes, checking and verifying the effects of each modification before implementing the next change.

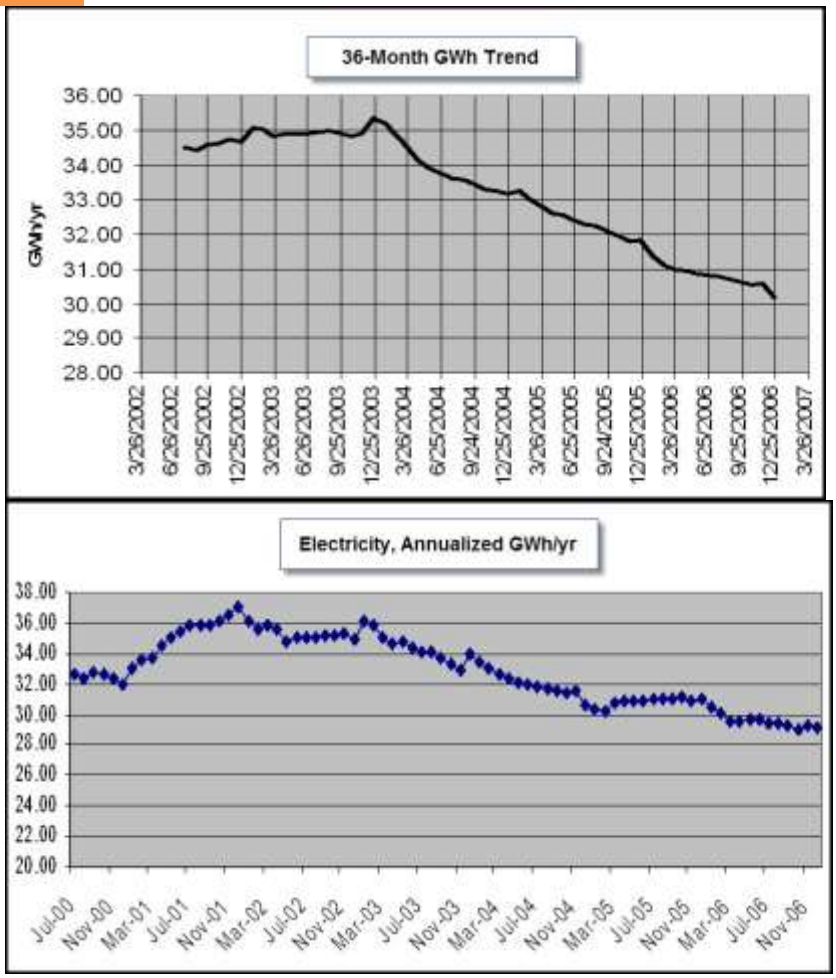
MAJOR CHANGES

- RE-TUNED UNOCCUPIED MODES
- RE-TUNED VARIABLE CHILLED WATER PUMPS AND CHILLERS
- INSTALLED DISCHARGE AIR TEMPERATURES AND PRESSURE RESET
- CHANGED DEAD BANDS ON INTERIOR AND EXTERIOR

02 BUILDING PERSONALITY, SLIDE 4

- Building engineers complained the building would not recover. Staff proved it COULD recover.
- Reduced the use of the three secondary chilled water pumps to one or two. Chilled water reset to between 42°F and 48°F based on humidity and loads at coils, instead of maintaining it at a constant 42°F. After the building owner repaired the smaller chiller, the building was able to run only the smaller chiller at night (previously had been running two large chillers).
- Reset based on warmest interior and coolest exterior zones.
- This allowed for floating of temperatures.

CAN IT WORK?



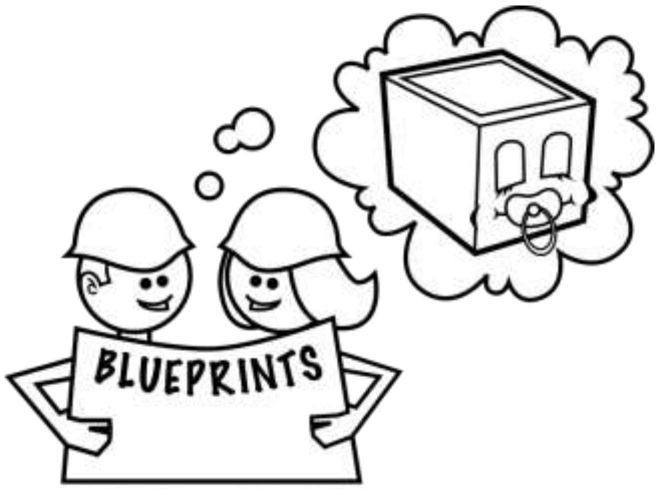
02 BUILDING PERSONALITY, SLIDE 5

- This is metering data that illustrates that re-tuning works (and takes time).
- The top graph shows the energy consumption rate for the building during the re-tuning project. The leftmost portion of the graph corresponds to the period when PNNL staff were collecting information and learning the building's personality. Note the steady downward trend of energy consumption once changes were implemented.
- The lower graph also shows the steady downward trend. Note the small upward spikes. These correspond to overrides or policy exceptions for the building that were mistakenly left in place. Through the re-tuning process, the staff was able to identify the causes of these spikes and recommend changes to counteract their effects.

- After re-tuning, the facility received an Energy Star rating, energy consumption was down 15 to 20%, and tenant complaints were down 35%. Peak savings were realized in shoulder months, which is a typical re-tuning finding.

BUILDING PERSONALITY

- BUILDINGS START AS CHILDREN

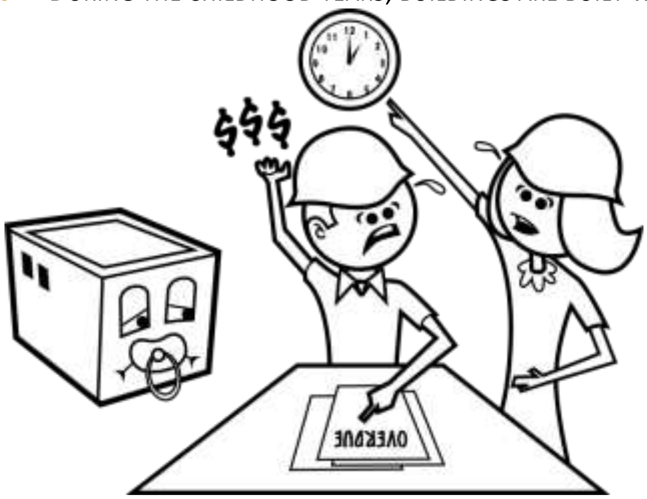


02 BUILDING PERSONALITY, SLIDE 6

- Buildings are designed by architects and engineers (the buildings' parents) with best-guess information for some weather conditions, inside load conditions, for a specific number of occupants, and for a specific solar gain and orientation.

BUILDING PERSONALITY (CONT.)

- DURING THE CHILDHOOD YEARS, BUILDINGS ARE BUILT WITH…



02 BUILDING PERSONALITY, SLIDE 7

- Low bid, tight schedules, limited inspections, and poor commissioning.

BUILDING PERSONALITY (CONT.)

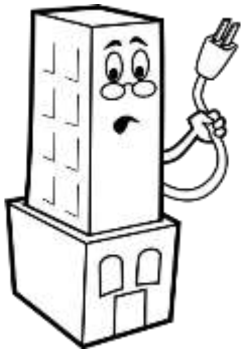
- BUILDINGS GROW TO BE TEENAGERS

02 BUILDING PERSONALITY, SLIDE 8

- They experience constant change, such as weather effects, staff loading changes, electrical computer loading changes, equipment malfunctions that are not repaired, design flaws that are not addressed, cubical and wall reconfigurations without moving diffusers, and poor maintenance of dampers, controls, valves, and air and water balance.

BUILDING PERSONALITY (CONT.)

- BUILDINGS GROW TO BE ADULTS

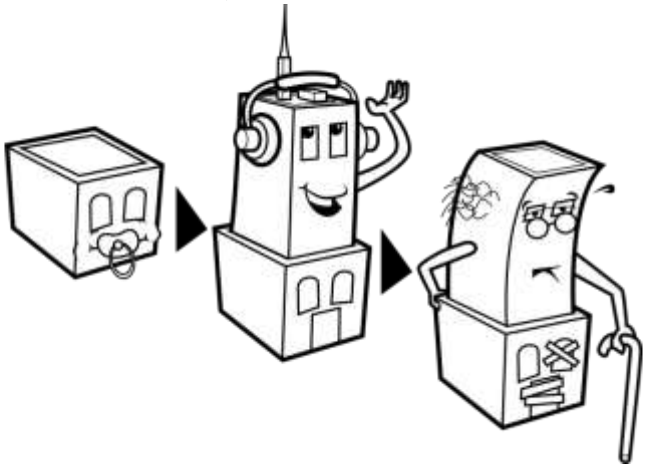


02 BUILDING PERSONALITY, SLIDE 9

- They experience high energy cost and increasing complaints. Small zones drive large systems. Poor operations based on complaint response instead of looking at the bigger picture. The poor maintenance experienced in the teenage years continues. The building and its systems are now older and with age things fall apart or do not work as well UNLESS taken care of.

BUILDING PERSONALITY (CONT.)

- AS WITH PEOPLE, YOU NEED TO GET TO KNOW YOUR BUILDING

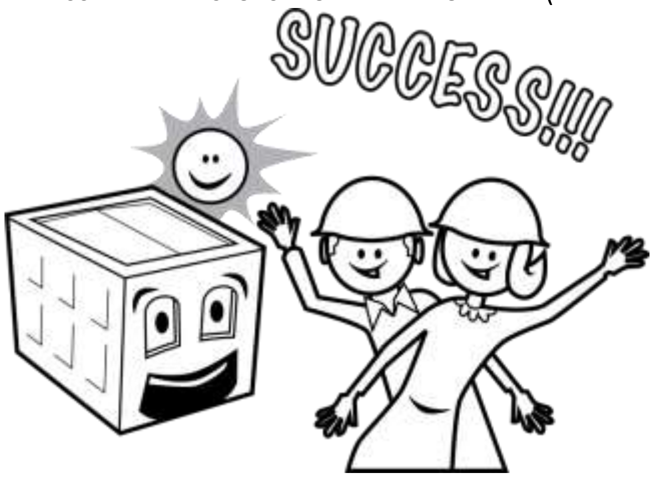


02 BUILDING PERSONALITY, SLIDE 10

- What is your building's personality? How does it respond to changing internal conditions? How does it respond to weather changes? What is its balance point, where no heating and no cooling are required? It takes time and history to actually learn a facility. That is why it's important to collect and analyze operational history data and history of complaints.

Building Personality (cont.)

- A psychologist will analyze a patient to learn a personality and then suggest changes in behavior or environment to help change that personality for a more acceptable response to the environment (a happier person)



02 Building Personality, Slide 11

- Personality tuning is the process of learning a building and then gently modifying its control parameters and sequence of operations to achieve more desirable results. You'll have a "happier" building with less energy usage and fewer customer complaints.

Chapter 3: Collect Initial Building Information

INSTRUCTOR GUIDANCE

TIME: 30 MINUTES

MATERIALS: POWERPOINT SLIDES 03 INITIAL DATA COLLECTION

LESSON GOAL: KNOW WHAT INFORMATION YOU NEED TO COLLECT INITIALLY

LEARNING OBJECTIVES:

- STATE THE PURPOSE OF COLLECTING INITIAL BUILDING INFORMATION
- LIST THE KINDS OF INFORMATION YOU NEED TO COLLECT

PURPOSE

- DETERMINE THE CHARACTERISTICS OF THE BUILDING AND ITS MECHANICAL SYSTEMS
- GATHER INFORMATION TO GUIDE SELECTION OF TREND LOGS TO SET UP IN THE NEXT STEP

03 INITIAL DATA COLLECTION, SLIDE 2

- The purpose of this step is to determine the overall design of the building and its systems.
- The information collected here will help you begin to understand your building's personality and will guide selection of data trending in Chapter 4.

INFORMATION TO COLLECT

- OVERALL BUILDING GEOMETRY
- TYPE OF HVAC SYSTEM(S)
- APPROXIMATE NUMBER OF ZONES
- APPROXIMATE NUMBER OF EACH MAJOR TYPE OF EQUIPMENT
- TYPE OF BUILDING AUTOMATION SYSTEM
- TYPES OF OCCUPANTS

03 INITIAL DATA COLLECTION, SLIDE 3

- Building geometry: approximate gross square feet, number of floors, general building shape
- HVAC systems
- Approximate number of zones
- Number of major types of equipment, including boilers, chillers, air handlers
- Type of building automation system (BAS) manufacturer, model, version. This will let you know its capabilities/capacity for trending data
- Occupants: Is the building mostly office space? Are there server rooms or floors? Are there any food service spaces (restaurants, cafeteria or coffee shops)?
- If you help manage the building, you probably have all or most of this information at your fingertips.

QUESTIONS?

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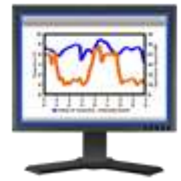
03 INITIAL DATA COLLECTION, SLIDE 4

- Ask if there are any questions so far.

Chapter 4: Pre-Re-Tuning Phase: Trend Data Collection and Analysis



INSTRUCTOR GUIDANCE

TIME: 30 MINUTES

MATERIALS: POWERPOINT SLIDES 04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS

LESSON GOAL: UNDERSTAND HOW TO USE THE ENERGY CHARTING AND METRICS (ECAM) TOOL

LEARNING OBJECTIVES:

- STATE THE PURPOSE OF TREND DATA COLLECTION AND ANALYSIS
- DEVELOP MONITORING PLANS
- UNDERSTAND HOW TO INTERPRET TREND GRAPHS

PURPOSE

- DETECT POTENTIAL OPERATIONAL PROBLEMS BEFORE VISITING THE BUILDING
- IDENTIFY PROBLEMS THAT REQUIRE TIME HISTORIES TO DETECT

04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 3

- Trend data will allow you to quickly see if, for example, occupancy scheduling is in place.
- Two weeks of measurements should show you if night and weekend setbacks are being used.
- Optimal time to analyze data is during shoulder months (fall or spring); this data should show greatest areas for improvement.
- If data analyzed is taken during holiday, this will allow you to quickly see if holiday scheduling is in place and working.

STEPS FOR TREND DATA COLLECTION

- DEVELOP A MONITORING PLAN
- IDENTIFY PROBLEMS THAT REQUIRE TIME HISTORIES TO DETECT

04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 4

- (Handout: Monitoring Plan Forms) The plan includes the points to trend, and for each point the planned trend start and end times, the length of measurement period (2 weeks recommended), time interval between measurements (5-15 minutes recommended, as high as 30 minutes), and measurement units.
- Suggested units for measurements are
  - Temperature: °F
  - Relative humidity: % or dewpoint - °F
  - Pressure: psig
  - Damper and valve positions: % of fully open
  - Fan speed: rpm
  - Fan status: on/off
  - Occupancy mode: occupied/unoccupied
  - Chiller load: % loaded, amps, kW, or tons.

  NOTE: When determining which and how many points to trend, consider how much data trending the building automation system can handle.

- Implementing trend logs will be discussed in detail a little later.

Air Handling Unit – Points to Monitor & Example Monitoring Plan

Air-Handling Unit Monitoring Plan

Building Name:	ABC Bank Building
Building Location:	123 4th Ave., Seattle, WA 99111
Date:	April 3, 2007
Planned Start Date/Time:	5/1/07 TBD
Planned End Date/Time:	5/15/07 TBD

Re-Tuning Technician Name:	John Doe, McDonalds Control Services
Contact Information:	(509) 555-5555; john.doe@mcs.com
Planned Measurement Period (hours, days or weeks)	2 weeks
Measurement Interval (seconds, minutes, or hours):	30 minutes

Floor:	1
Equipment Name:	AHU-1

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planed Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
OAT1	Outdoor air temperature					Degrees F
MAT1	Mixed air temperature					Degrees F
RAT1	Return air temperature					Degrees F
DAT1	Discharge air temperature					Degrees F
DATSP1	Discharge air temperature set point					Degrees F
PDIST1	Discharge Static Press					in. w.c.
MADamper1	Mixed air damper position					% open
Fan1	Fan status					on/off
Fan Speed1	Fan speed					rpm
CWV%1	Chilled water valve position					% open
HWV%1	Hot water valve position					% open
MODE1	Occupancy mode					Occupied/ Unoccupied

04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 5

- Note that the measurement period is 2 weeks and the interval is 30 minutes. The Measurement Description (highlighted in yellow) contains the points to trend.
- Ask the class why they think it's important to develop a monitoring plan. One answer you're trying to get is "So someone else can later see what has been trended and what might be missing."
- Anecdotally, another question to ask the class is why a person's heart rate, blood pressure or weight measurements must be taken over time before any analysis can be performed?
- Unless you characterize the building during occupied and unoccupied periods you don't know whether or not systems are being turned off when the building is unoccupied. In addition, to evaluate certain systems, e.g., economizer operations, you will need different outdoor and indoor conditions. Time history of data will allow for such comparisons/analysis.
- Also, a good time to trend short-term data is either spring or fall, when there is significant swing the outdoor temperatures.
- Note that most of the time the occupied/unoccupied mode is represented as 100/0 or 1/0.

Zone/VAV Box – Points to Monitor & Example Monitoring Plan

Building Name:	ABC Bank Building
Building Location:	123 4th Ave., Seattle, WA 99111
Date:	April 3, 2007

Re-Tuning Technician Name:	John Doe, McDonalds Control Services
Contact Information:	(509)555-5555; john.doe@mcs.com

Planned Start Date/Time:	6/1/07 TBD
Planned End Date/Time:	6/15/07 TBD

Planned Measurement Period (hours, days or weeks):	2 weeks
Measurement Interval (seconds, minutes, or hours):	30 minutes

Floor:	1
Equipment Name:	VAV1-1

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planed Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
T1-1	Zone air temperature					Degrees F
VAV%1-1	VAV box damper position					% open
REHEAT%1-1	VAV box reheat valve position					% open
MODE1-1	Zone occupancy mode					Occupied/ Unoccupied

04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 6

- Again, focus on period, interval, and measurement (trend points).

Physical Plant – Points to Monitor & Example Monitoring Plan

Building Name:	ABC Bank Building
Building Location:	123 4th Ave., Seattle, WA 99111
Date:	April 3, 2007

Re-Tuning Technician Name:	John Doe, McDonalds Control Services
Contact Information:	(509)555-5555; john.doe@mcs.com

Planned Start Date/Time:	5/1/07 TBD
Planned End Date/Time:	5/15/07 TBD

Planned Measurement Period (hours, days or weeks):	2 weeks
Measurement Interval (seconds, minutes, or hours):	30 minutes

Mechanical Room Location:	Basement 1

Equipment Name	Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
Chiller Plant	CWST	Chilled water supply temperature					Degrees F
Chiller Plant	CWST-SP	Chilled water supply temperature set point					Degrees F
Chiller Plant	CWRT	Chilled water return temperature					Degrees F
Chiller Plant	CNDST	Condenser supply temperature (temperature of water returning from the cooling tower)					Degrees F
Hot Water Plant	HWST	Hot water supply temperature					Degrees F
Hot Water Plant	HWRT	Hot water return temperature					Degrees F

04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 7

This is a monitoring plan for the physical plant.

PHYSICAL PLANT – POINTS TO MONITOR & EXAMPLE MONITORING PLAN (CONT.)

Equipment Name	Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planed Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
Chiller 1	CHLOAD1	Chiller 1 load					Tons
Chiller 1	CHSTAT1	Chiller 1 status (only needed if load is not available)					On/off
Chiller 1	CNDRT1	Condenser return temperature (temperature of water leaving the condenser)					Degrees F
Chiller 2	CHLOAD2	Chiller 2 load					Tons
Chiller 2	CHSTAT2	Chiller 2 status (only needed if load is not available)					On/off
Chiller 2	CNDRT2	Condenser return temperature (temperature of water leaving the condenser)					Degrees F

04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 8

- Create a table for each chiller in the physical plant.

PHYSICAL PLANT – POINTS TO MONITOR & EXAMPLE MONITORING PLAN (CONT.)

Equipment Name	Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planed Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
Pump 1	P1-STATUS	Status of Pump 1					On/off
Pump 2	P2-STATUS	Status of Pump 2					On/off
Pump 3	P3-STATUS	Status of Pump 3					On/off

04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 9

Create a new row for each pump.

IMPLEMENTING MONITORING PLAN: SETTING UP TREND LOGS

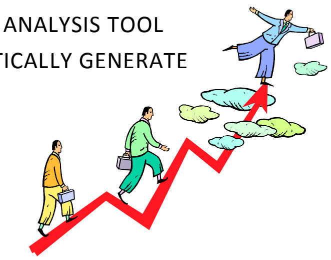
- TREND LOGS ARE SET UP IN THE BUILDING AUTOMATION SYSTEM (BAS)
- EACH BAS HAS ITS OWN PROCEDURES FOR SETTING UP TREND LOGS

04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 10

- Because each building automation system (BAS) is different, you will need to consult the BAS manual or get help to determine how to set up trend logs for your BAS. Better yet, find someone who knows how and have him or her show you.
- However, we will cover how to analyze the trended data in the next several slides.

ANALYZE TREND LOG DATA WITH ECAM – MAJOR STEPS

- DOWNLOAD TREND LOG DATA FILES FROM BAS
- FORMAT DATA FILES FOR COMPATIBILITY WITH THE ECAM SPREADSHEET ANALYSIS TOOL
- OPEN DATA FILES IN ECAM SPREADSHEET ANALYSIS TOOL AND AUTOMATICALLY GENERATE GRAPHS
- REVIEW GRAPHS TO IDENTIFY OPERATIONAL ISSUES
- RECORD OPERATIONAL ISSUES FOR REFERENCE DURING RE-TUNING



04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 11

- This is just an overview of the major steps for using the Energy Charting and Metrics (ECAM) tool. A demo will come a little later.
- First, download the trend log data files from the building automation system.
- Next, format the files so that they are compatible with ECAM.
- Next, analyze the graphs to identify operational issues.
- Finally, record these issues for reference during re-tuning.
- The ECAM tool and user manual is available for download (www.pnnl.gov/buildingretuning).

Download Trend Log Data Files

- Download or copy the trend log data files from the BAS or workstation for formatting
- If the data are not in CSV (comma-separated variable) format, convert to CSV

04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 12

- Download the trend log data files from the building automation system
- All files must be in CSV or XLS format to work with ECAM. ECAM needs all the point to be used in one single file – multipoint file (multiple points per file—time stamp followed by multiple point data).
- If you have single point format (one point or variable per file—time stamp and value), use Universal Translator (UT) tool to merge the multiple single points files into a single multiple point file. The UT tool can be downloaded from the following website: http://utonline.org/cms/
- You can't mix single-point and multipoint files. Use one or the other. Multi-point is preferred, but some older systems use only single-point.

EXAMPLE OF SINGLE-POINT DATA FILE FORMAT

```
Time,    Outdoor Temp.Trend (deg F)
4/20/07 2:45:00 PM PDT,   61.96875
4/20/07 2:50:00 PM PDT,   61.03125
4/20/07 2:55:00 PM PDT,   60.6875
4/20/07 3:00:00 PM PDT,   60.6875
4/20/07 3:05:00 PM PDT,   59.6875
4/20/07 3:10:00 PM PDT,   58.625
4/20/07 3:15:00 PM PDT,   61.65625
4/20/07 3:20:00 PM PDT,   59.5625
4/20/07 3:25:00 PM PDT,   59.5
4/20/07 3:30:00 PM PDT,   59.875
4/20/07 3:35:00 PM PDT,   61.3125
4/20/07 3:40:00 PM PDT,   61.3125
4/20/07 3:45:00 PM PDT,   59.5
4/20/07 3:50:00 PM PDT,   60.6875
4/20/07 3:55:00 PM PDT,   60.5
```

04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 13

- This is an example of single-point data file format (one point trended per line).
- Multipoint is preferred, but some older systems only use single-point.

EXAMPLE OF MULTI-POINT DATA FILE FORMAT

```
Date / Time,   Sf-1 Speed (%),   Sf-2 Speed (%),   Sf-3 Speed (%),  OA_TEMP),   OCCCMD,
5/2/2007 0:00,   0,   0,   0,  58.77789,   0,   62.06757,   0,   0,   0,   0.010427,
5/2/2007 0:30,   61.7719,   0,   0,   52.62024,   0,   72.58334,   1,   100,   0,   1.1
5/2/2007 1:00,   59.71371,   0,   0,   53.07013,   0,   72.41461,   1,   100,   0,   1.
5/2/2007 1:30,   55.69472,   0,   0,   52.84518,   0,   72.3584,   1,   100,   0,   1.0
5/2/2007 2:00,   55.59563,   0,   0,   52.84518,   0,   72.33029,   1,   100,   0,   1.
5/2/2007 2:30,   55.88474,   0,   0,   52.98575,   0,   72.18973,   1,   100,   0,   1.
5/2/2007 3:00,   55.88474,   0,   0,   52.31094,   0,   72.16162,   1,   100,   0,   1.
5/2/2007 3:30,   55.88474,   30.16013,   0,   52.42343,   0,   72.021,   1,   100,   0,
5/2/2007 4:00,   50.42294,   0,   0,   52.42343,   0,   72.16162,   1,   100,   0,   1.
5/2/2007 4:30,   50.3317,   0,   53.9305,   52.42343,   0,   72.47089,   1,   100,   0,
5/2/2007 5:00,   64.45383,   60.54897,   61.87724,   51.86108,   1,   72.47089,   1,
5/2/2007 5:30,   75.39667,   60.54897,   59.67387,   51.77673,   1,   72.21783,   1,
5/2/2007 6:00,   75.40579,   60.54897,   59.26752,   51.72049,   1,   72.18973,   1,
5/2/2007 6:30,   75.40579,   60.54897,   58.20168,   51.86108,   1,   72.24594,   1,
```

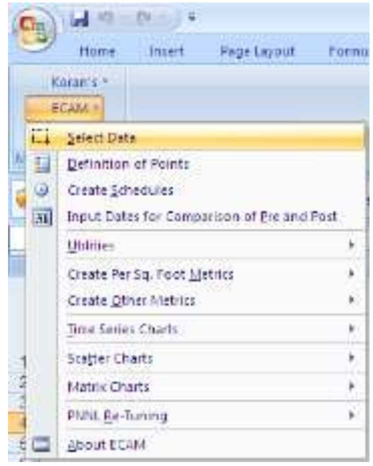
04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 14

- This is an example of a multipoint data file format, with several trend points per line.

Energy Charting and Metrics—ECAM

Five Easy Steps:

1. Select data from existing spreadsheet
2. Map points
3. Create schedules (optional)
4. Input energy project dates (optional)
5. Create metrics and charts



04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 15

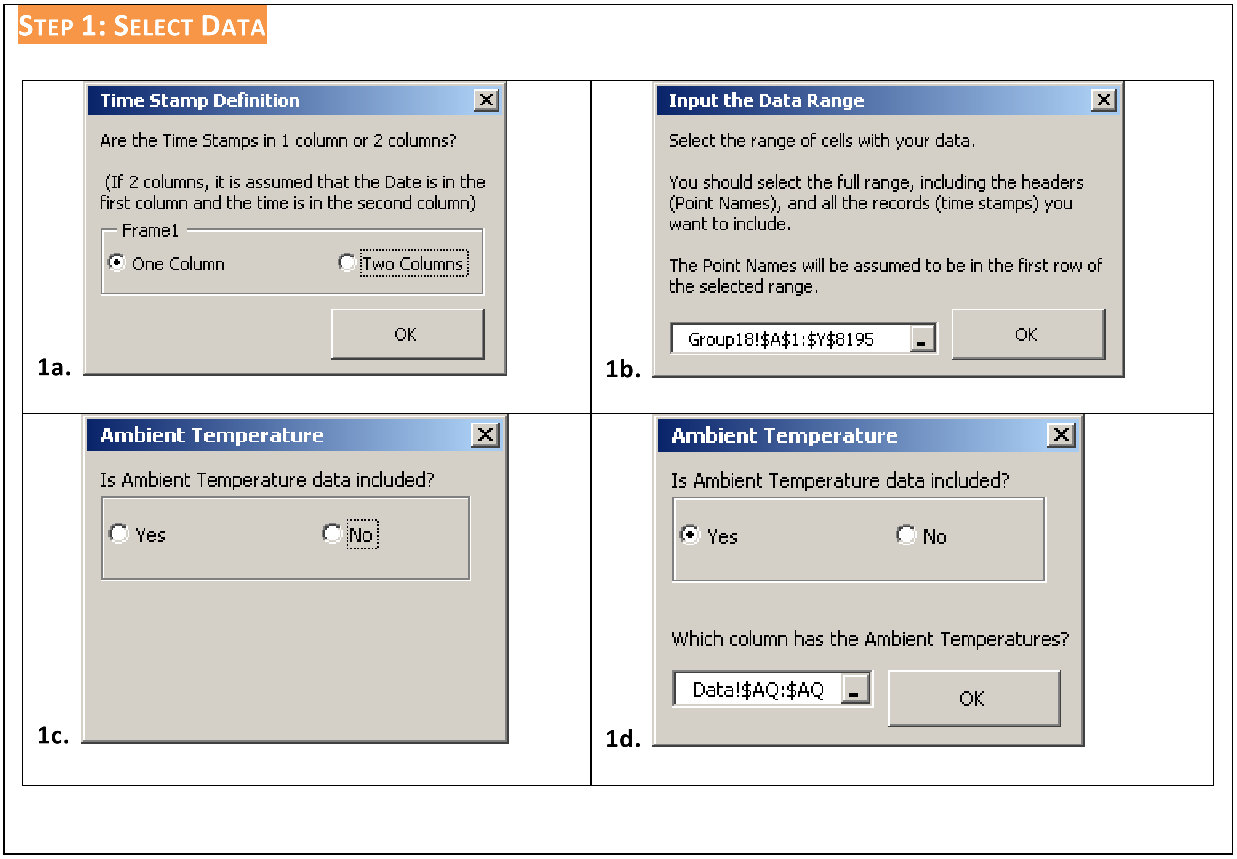
- We will use trend log data in ECAM to investigate issues.
- We will look at some examples of what to look for.
- ECAM cannot work with single-point data files.
- The ECAM user manual is an appendix to this Instructor Guide. Instructors should familiarize themselves with the tool before demonstrating for class.
- The next several slides show screenshots of the ECAM tool. It is preferable to demonstrating the tool.

USER'S DATA—EXAMPLE

DateTime	Outside Dry Bulb	325 COMMON CHWS	326 COMMON CHWR	328 CHILLER 1 AMPS	342 COM CDW SUPPLY	343 COM CDW RETURN	345 A CHILLER ON	414 SCHWP-5 KW	415 SCHWP-6 KW	416 SCHWP-7 KW
8/23/04 12:00 AM	67.4	41.9	48.5	226.1	69.2	77.3	100	0	5	0.8
8/23/04 12:15 AM	67.5	42	48.7	224.3	69	77.1	100	0	4.8	1.3
8/23/04 12:30 AM	67.3	41.6	47.6	206.9	68.9	76.3	100	0	4.7	1.6
8/23/04 12:45 AM	67.1	41.8	47.7	206.7	68.5	75.8	100	0	4.6	1.3
8/23/04 1:00 AM	67.1	42.2	47.6	195.9	68.2	75	100	0	4.7	1.4
8/23/04 1:15 AM	67	41.8	47	193.8	68.1	74.8	100	0	4.6	0
8/23/04 1:30 AM	67	42	46.2	168.1	67.6	72.9	100	0	4.7	0
8/23/04 1:45 AM	66.8	41.9	45.3	152.1	67.5	71.9	100	0	4.6	0.6
8/23/04 2:00 AM	67	42.2	45.3	150.2	67.8	71.9	100	0	4.6	0.6
8/23/04 2:15 AM	67.1	42	48.5	0	67.6	74.6	100	0	4.8	0.9
8/23/04 2:30 AM	67.1	41.6	47.7	0	68.8	75.7	100	0	4.5	0.5
8/23/04 2:45 AM	67	42	48.4	0	68.2	75.1	100	0	4.7	0.8
8/23/04 3:00 AM	67.1	41.6	47.5	0	68.4	75.1	100	0	4.5	0.9
8/23/04 3:15 AM	67.2	41.7	47.5	0	68.3	74.8	100	0	4.7	0.8
8/23/04 3:30 AM	67.4	42.4	47.9	0	68.2	74.4	100	0	4.6	0.8
8/23/04 3:45 AM	67.4	43.5	48.6	0	68.3	73.8	100	0	4.7	0.9
8/23/04 4:00 AM	67.5	45	49.4	0	68.1	73	100	0	4.8	0

04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 16

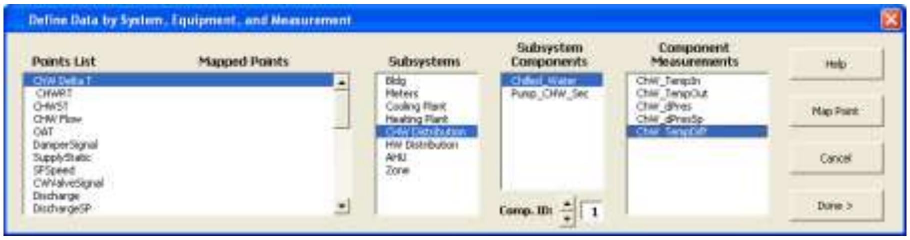
- Ask the class: What points are being trended?
- Ask the class: At what interval (15 minutes)?



04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 17

- If you select two columns, the date will be the first column and time will be the second.
- Select the full range, including headers (point names) and all records (time stamps) that you want to include.
- Choose whether to include ambient temperature data.
- If you choose yes, then you need to specify which column contains the ambient temperature data.

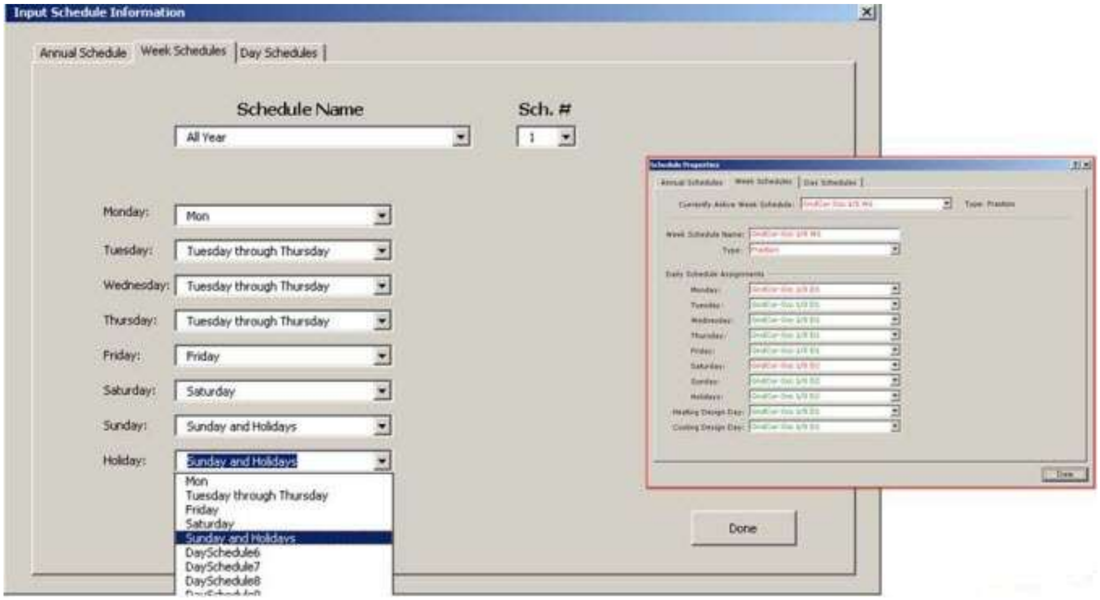
STEP 2: MAP POINTS



04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 18

- User's points are mapped to common point names as per *A Specifications Guide for Performance Monitoring Systems* (available for download at http://cbs.lbl.gov/performance-monitoring/specifications/).
- Multiple systems can be mapped using the "Comp. ID" feature.

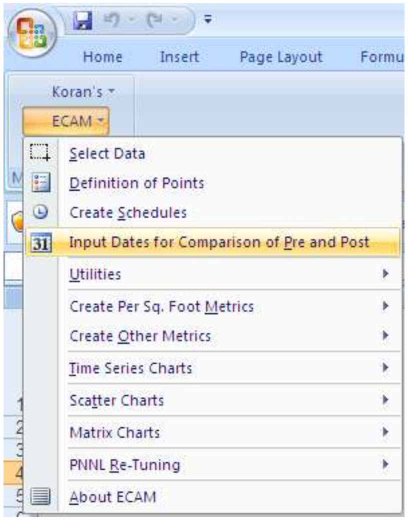
Step 3: Create Schedule

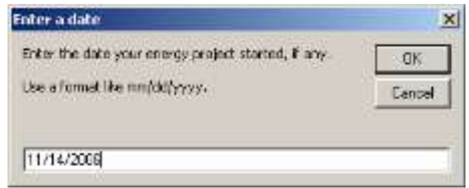


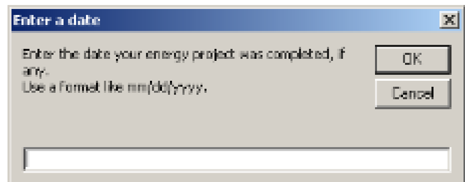
04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 19

- You can create a schedule of known occupied and unoccupied times. If you do not set the schedule, 24/7 operation is assumed.

Step 4: Input Energy Project Dates







04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 20

- Enter the project start and end dates, using the same format in both places. If the project has not ended, leave the field blank.

Preprocessing

- Time stamp disaggregation
- Day typing
- Occupancy
- Pre/Post Energy Project
- Normalizations
- Calculations

04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 21

- Day typing—For example, you can choose to view and analyze all Tuesdays or all weekends and holidays for the selected period.
- Occupancy—occupied or unoccupied periods.
- Pre/Post—to compare the start date with the end date; shows the effects of re-tuning (or weather or seasonal effects, etc.).
- Normalization—related to outdoor air temperature; for example, you can run graphs to compare this month to the previous month or the same month in the previous year.

Fields Added

DateTime	Year	Month	MonthYr	Day	Hour	Date	Time	Weekday	Daytype	Holiday	Occupancy
4/22/07 12:00 AM	2007	April	Apr 2007	22	0	4/22/2007	12:00 AM	Sunday	Sunday	No	Unocc
4/21/07 11:45 PM	2007	April	Apr 2007	21	23	4/21/2007	11:45 PM	Saturday	Saturday	No	Unocc
4/21/07 11:30 PM	2007	April	Apr 2007	21	23	4/21/2007	11:30 PM	Saturday	Saturday	No	Unocc
4/21/07 11:15 PM	2007	April	Apr 2007	21	23	4/21/2007	11:15 PM	Saturday	Saturday	No	Unocc
4/21/07 11:00 PM	2007	April	Apr 2007	21	23	4/21/2007	11:00 PM	Saturday	Saturday	No	Unocc
4/21/07 10:45 PM	2007	April	Apr 2007	21	22	4/21/2007	10:45 PM	Saturday	Saturday	No	Unocc
4/21/07 10:30 PM	2007	April	Apr 2007	21	22	4/21/2007	10:30 PM	Saturday	Saturday	No	Unocc
4/21/07 10:15 PM	2007	April	Apr 2007	21	22	4/21/2007	10:15 PM	Saturday	Saturday	No	Unocc
4/21/07 10:00 PM	2007	April	Apr 2007	21	22	4/21/2007	10:00 PM	Saturday	Saturday	No	Unocc
4/21/07 9:45 PM	2007	April	Apr 2007	21	21	4/21/2007	9:45 PM	Saturday	Saturday	No	Unocc
4/21/07 9:30 PM	2007	April	Apr 2007	21	21	4/21/2007	9:30 PM	Saturday	Saturday	No	Unocc
4/21/07 9:15 PM	2007	April	Apr 2007	21	21	4/21/2007	9:15 PM	Saturday	Saturday	No	Unocc
4/21/07 9:00 PM	2007	April	Apr 2007	21	21	4/21/2007	9:00 PM	Saturday	Saturday	No	Unocc
4/21/07 8:45 PM	2007	April	Apr 2007	21	20	4/21/2007	8:45 PM	Saturday	Saturday	No	Unocc
4/21/07 8:30 PM	2007	April	Apr 2007	21	20	4/21/2007	8:30 PM	Saturday	Saturday	No	Unocc
4/21/07 8:15 PM	2007	April	Apr 2007	21	20	4/21/2007	8:15 PM	Saturday	Saturday	No	Unocc
4/21/07 8:00 PM	2007	April	Apr 2007	21	20	4/21/2007	8:00 PM	Saturday	Saturday	No	Unocc
4/21/07 7:45 PM	2007	April	Apr 2007	21	19	4/21/2007	7:45 PM	Saturday	Saturday	No	Unocc
4/21/07 7:30 PM	2007	April	Apr 2007	21	19	4/21/2007	7:30 PM	Saturday	Saturday	No	Unocc

04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 22

- This is an example of user-selected settings that will be used to generate the graphs.
- This is what they would see after selecting the data for analysis.

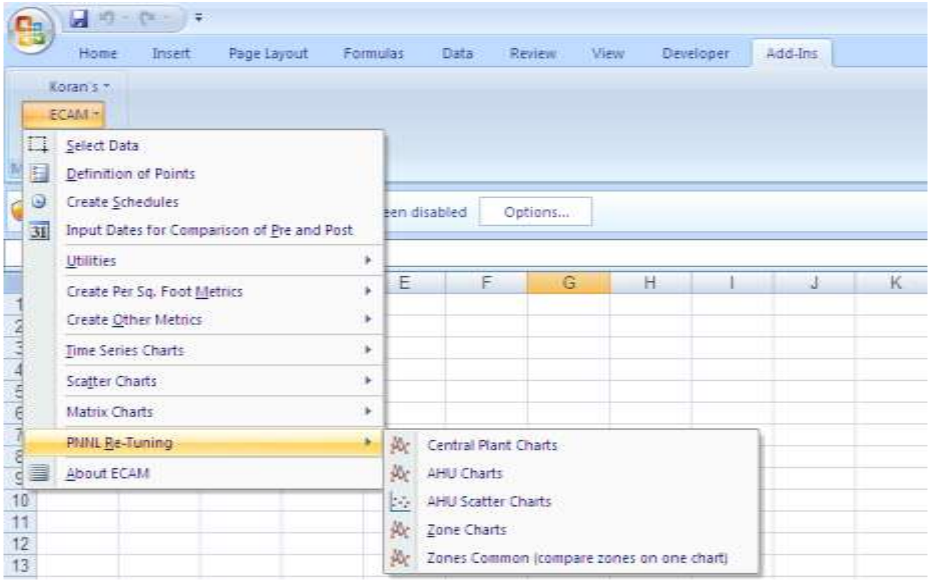
Re-Tuning

- Re-tuning
- Output
- Re-Tuning Charts
- Programming Process

04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 23

- Re-tuning is the last step in ECAM.
- We will discuss the appearance, including layout and features used for data filtering.
- Worksheets can be used to add charts and points.
- Finally, we will discuss the programming process.

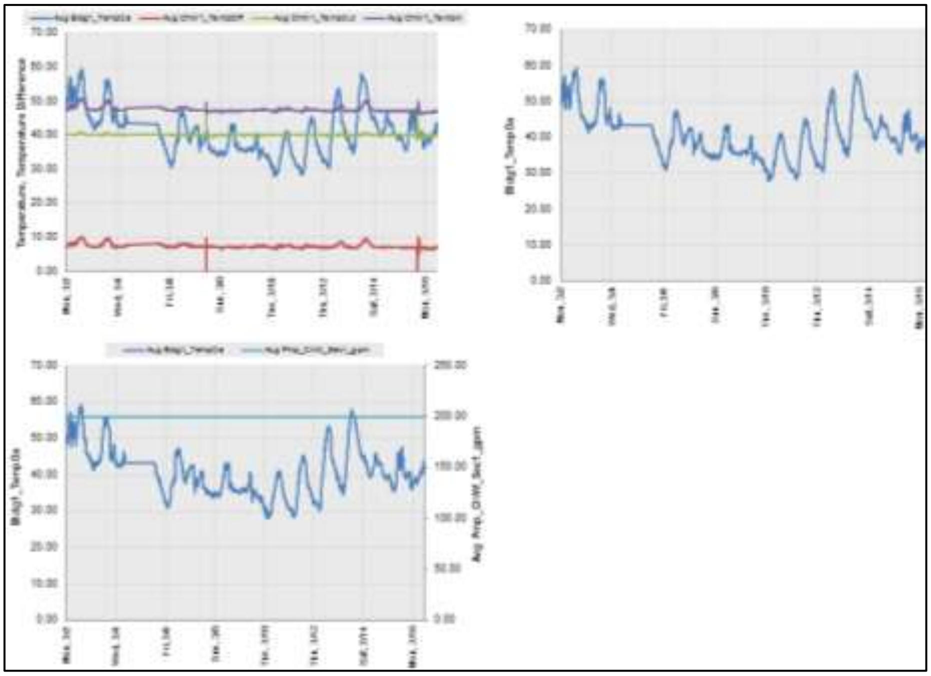
RE-TUNING MENU



04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 24

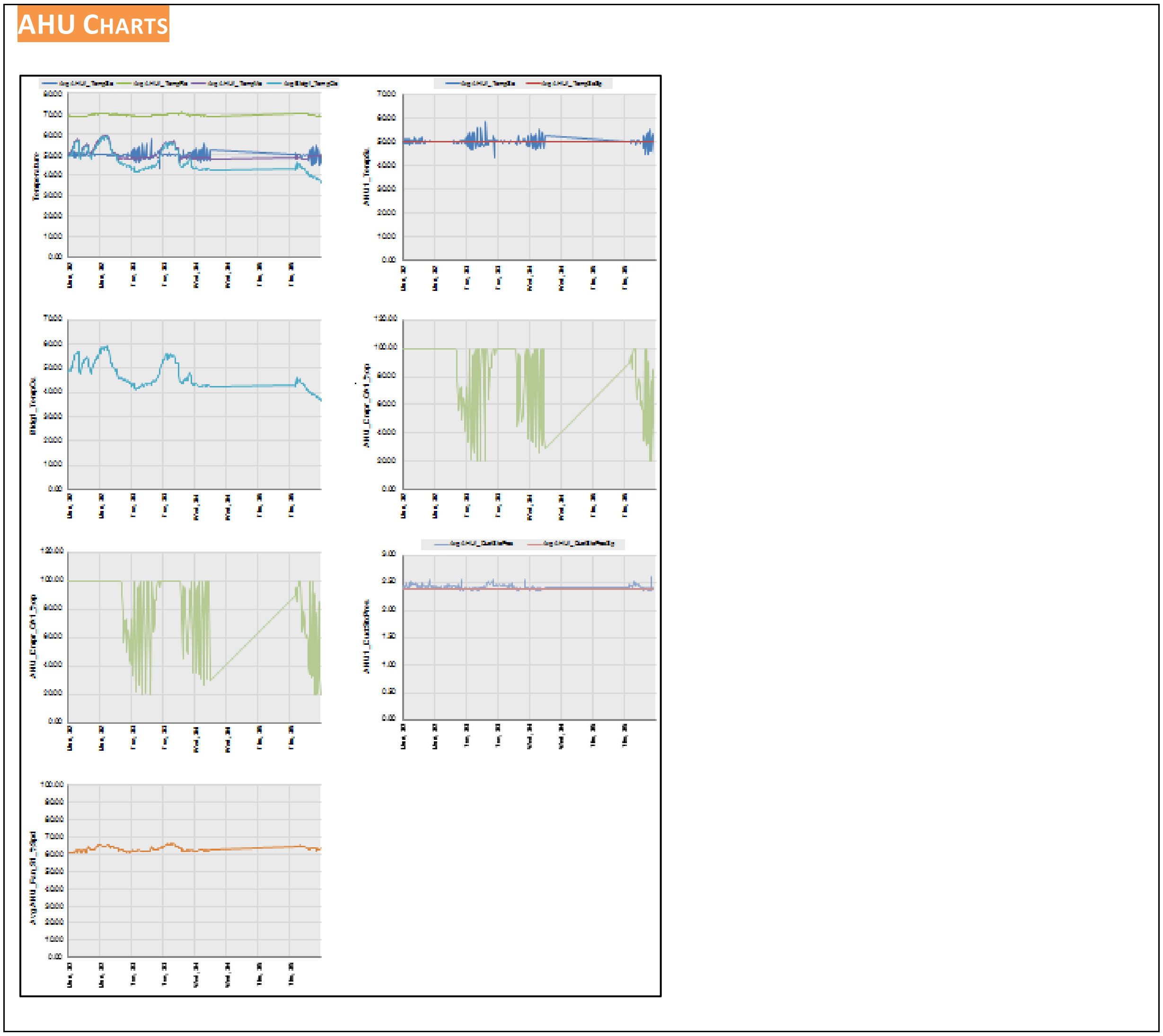
- From the ECAM menu, select PNNL Re-tuning.

CENTRAL PLANT CHARTS



04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 25

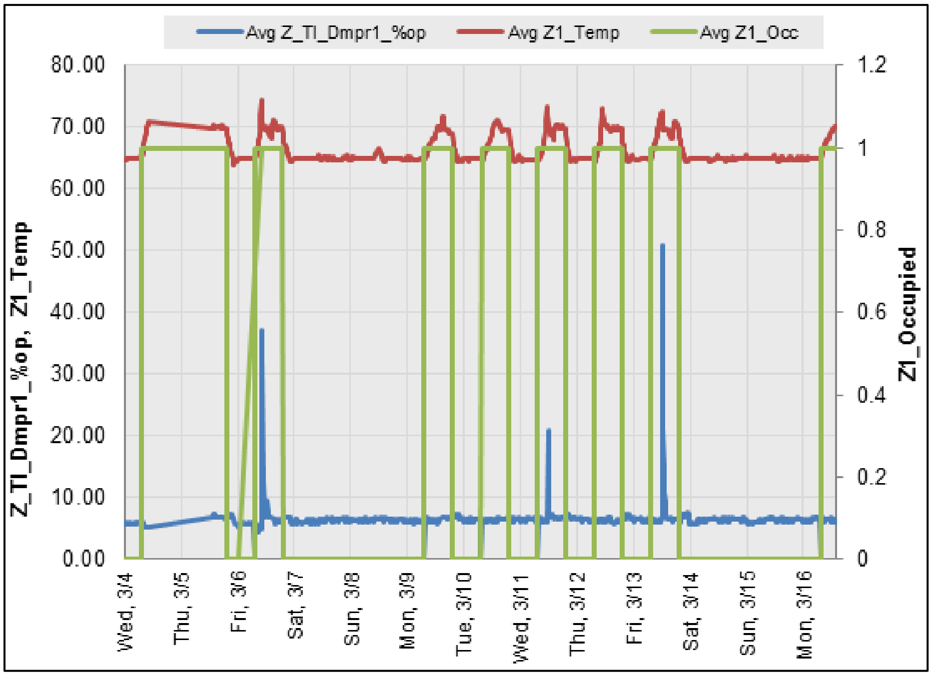
- These are examples of ECAM-generated charts:
  - Chilled water supply, return, ΔT, and OAT (outdoor-air temperature) vs. Time.
  - Hot water supply, return, ΔT (difference between return and supply hot water temperature), and OAT vs. Time.
  - Chilled water flow and OAT vs. Time.



04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 26

- More example charts—these are for the air handler
- Points to plot:
    - Outdoor, return, mixed, and discharge air temperatures vs. time.
    - Discharge air temperature and discharge air temperature set point vs. time.
    - Outdoor air fraction and damper position signal vs. time.
    - Outdoor and return air temperatures, damper position signal vs. time.
    - Damper, chilled water valve and hot water valve position signals vs. time.
    - Damper position signal vs. time.
    - Discharge static pressure vs. time.
    - Supply fan speed, status, and static pressure vs. time.
    - Return fan speed and status vs. time.

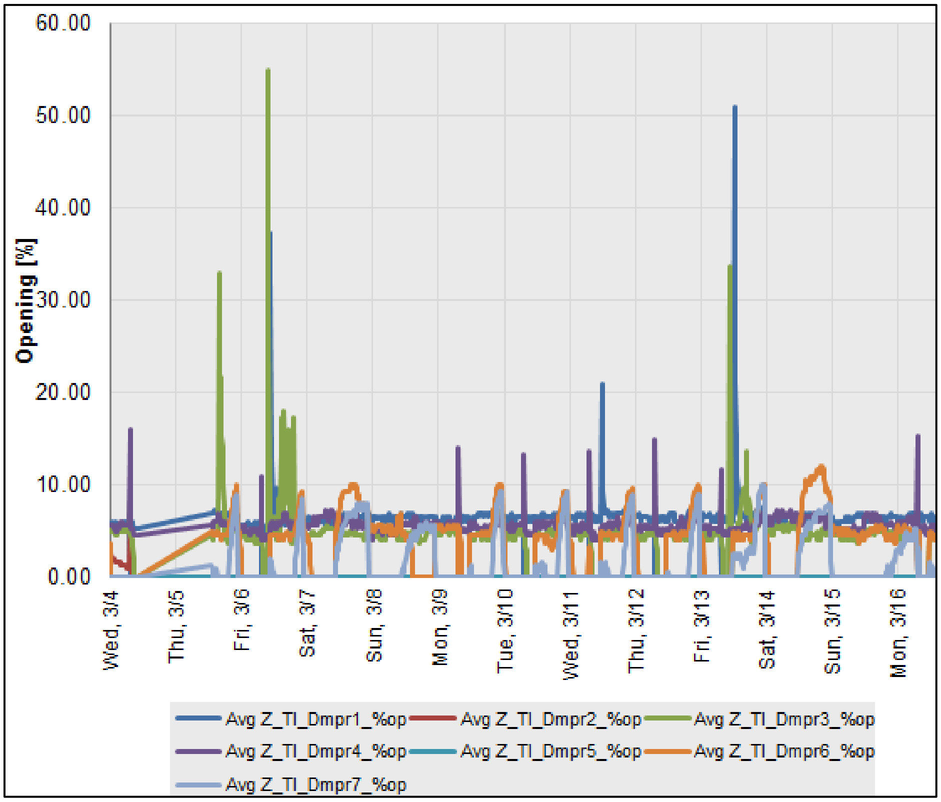
Zone Charts



04 Pre-Re-Tuning Trend Data Collection & Analysis, Slide 27

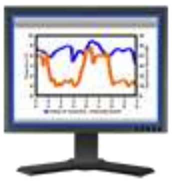
- Another example ECAM-generated chart.
- For zone trending, plot the following points: zone damper position signal, reheat valve position signal, occupancy mode, and zone temperature vs. time.

ALL ZONES CHARTS



04 PRE-RE-TUNING TREND DATA COLLECTION & ANALYSIS, SLIDE 28

- Plot zone damper position vs. time for all zones.



Chapter 5: Air Handling Units: Pre-Re-Tuning and Trending

Instructor Guidance

Time: 45 minutes

Lesson Goal: Learn how to re-tune air handling units

Learning Objectives:

- Collect basic information for air handlers
- Understand the points needed for trend graph analysis for air handlers
- Develop monitoring/Trending plan for air handlers
- Generate air handler trend graphs
- Analyze air handler trend graphs and identify opportunities for improvement
- Re-tune the air handlers

Introduction to Air Handling Units

- All-air system
- Air and water system
- All-water system
- Others

05 Pre-Re-Tuning - SDVAV, Slide 3

- This slide shows the system configuration (supply side) of the different types of AHUs.
- All-air systems can be constant volume (single duct/dual duct) or variable volume (single duct/dual duct). All-air systems are the main focus of this section. Other systems are:
  - Air and water systems (induction unit)
  - All-water systems (fan coil unit)
  - Baseboard radiation
- Unitary refrigerant-based unit - In a direct-expansion (DX) unitary system, the evaporator is in direct contact with the air stream, so the cooling coil of the airside loop is also the evaporator of the refrigeration loop. The term "direct" refers to the position of the evaporator with respect to the airside loop.
- Heat pump is a form of DX system with the ability to provide both cooling and heating depending on the need by reversing the flow of refrigerant through the indoor and outdoor coils of the unit.

System Type: All-Air System

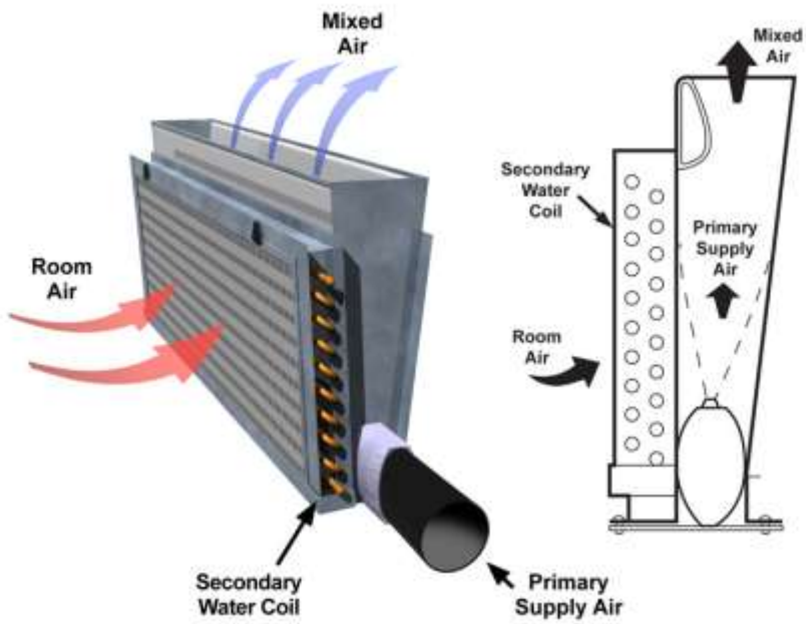
System Type

	Constant Volume	Variable Volume
Single Duct	Single Zone Unit	Single Zone VAV
	Multiple Zone with Reheat	Single Duct VAV
Dual Duct	Dual Duct Constant Volume (DDCV)	Dual Duct Variable Air Volume (DDVAV)
	Multi-Zone Unit	
	Texas Multi-Zone Unit	

05 Pre-Re-Tuning - SDVAV, Slide 4

- With all-air SDVAV systems, spaces are cooled primarily by air supplied to them from the central air conditioning equipment.
- The table shows variables for single-duct and dual-duct all-air systems.
- Multi-zone systems have a cold/hot deck in the mechanical room and typically have constant air flow. They also have zone mixing dampers at the central air handling equipment. These zone mixing dampers are controlled from the zone thermostat and mix cold air from the cold deck with heated air from the hot deck. They can also allow air only from the cold deck or only from the hot deck. Another variation of this has a middle deck with no heating or cooling and allows only the air being introduced from outside and returned (mixing plenum) when the zone has no need for heating or cooling.
- A Texas multi-zone system has a cooling coil in the cold deck and no coil in the bypass deck. Each zone has a separate heating coil. Generally, it supplies a constant volume of air to each zone, and room temperature is controlled at a room thermostat by varying supply air temperature.

Air and Water System Type: Induction Unit

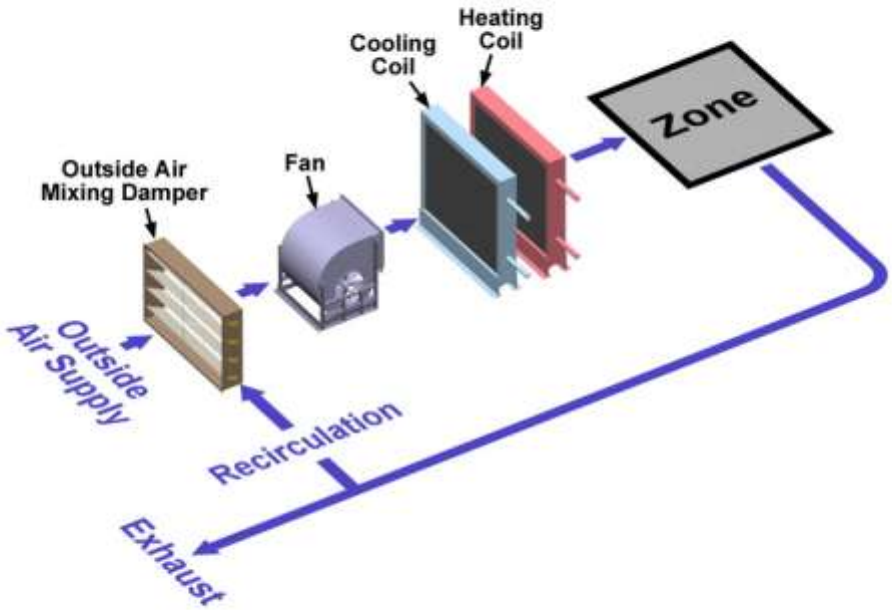


05 Pre-Re-Tuning - SDVAV, Slide 5

- NOTE: If class has HVAC background, this and the next slide can be eliminated. They simply show different types of fan coil units.
- Chilled water is used to provide sensible cooling in the zone.
- Air from AHU provides fresh air for ventilation and also carries moisture from the zone
- High-duct velocity pressure is required to induce air flow across the coil from the room. If the velocity pressure is not high enough at the induction unit, the ability to “induce” air flow across the cooling coil is compromised. Thus, the reduction of static pressure (inlet vanes/VFDs) to save energy can have a negative effect on effective comfort cooling.
- Unit is usually floor-mounted under a window and found primarily in perimeter office spaces.
- In some cases, it is not uncommon to find two coils (one for heating and one for cooling) or a single coil that is designed as a 4-pipe or 3-pipe system, where either hot or chilled water can be used as the water medium for final heating/cooling effect. There can be numerous control strategies associated with these systems that have been used in various parts of the country.

- If obstructions are placed on top of induction unit outlet or furniture is placed in front of grill where room air would pass across the coil (this often occurs), the system will not perform as designed. Filtering is also important. If filters are not replaced or in use, the secondary coil will plug up and the ability to flow (induce) air from the room will cease. The picture should show a filter.

All-Water System Type: Fan Coil Unit



05 Pre-Re-Tuning - SDVAV, Slide 6

- In a fan coil unit, cooling and dehumidification are provided by circulating chilled water.
- Heating is provided by supplying hot water through the same or separate coil using water distribution from central equipment.
- It includes fan coil, unit ventilator, one or two heat exchanger coils, filter, and economizer damper sections.

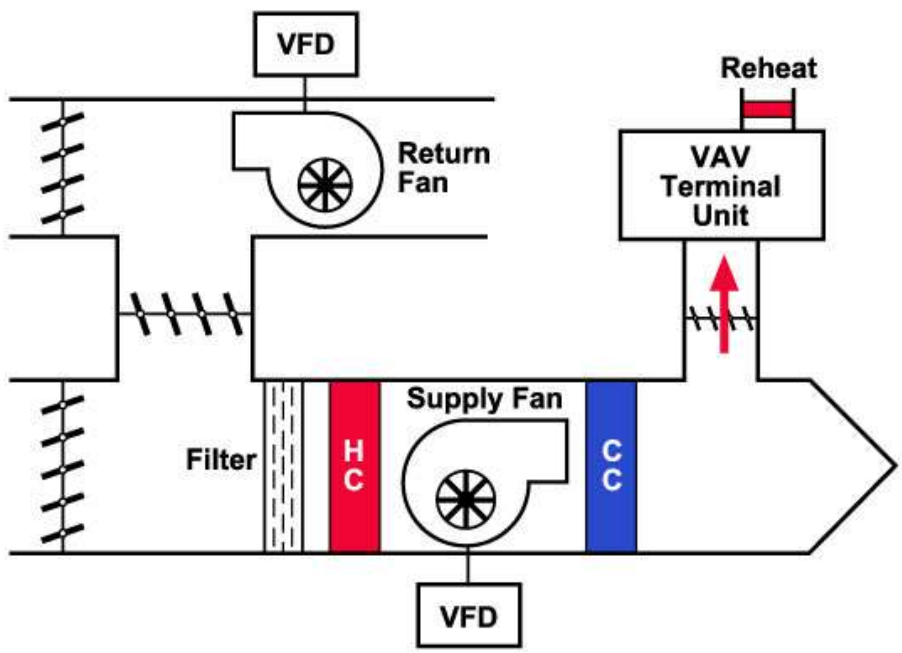
Example of Basic Information

Questions List	Answer
Unit Number	AHU-1
Serving Area	First Floor East & North side Exterior Zone
Single Duct/Dual Duct/Single Zone	Single Zone
VFD installed (Yes/No)	Yes
DDC Control (D) or Pneumatic control (P)	D
Supply Fan/Return Fan Motor Size (HP)	5/2.5
Schematic Diagram	Yes

05 Pre-Re-Tuning - SDVAV, Slide 7

- You need to collect some basic information about the air-handling units—this slide shows an example. Some general information you want to collect include:
    - What type of AHU is used in the building?
    - For a system flow diagram, try to get a building automation system graphic snapshot, if graphics are available.
    - Pneumatic or direct digital control?
- Specific information to collect includes any known operations and maintenance issues and mechanical schedule (e.g., fan motor size).

Single-Duct Variable Air Volume Unit



05 Pre-Re-Tuning - SDVAV, Slide 8

- In VAV systems, chilled air is distributed to spaces from an air-handling unit, and the temperature of individual spaces is controlled by throttling the quantity of air into each space. The throttling is accomplished by terminal units that are controlled by the space thermostats for both heating and cooling.
- VAV systems were originally introduced as a more efficient alternative to constant-volume reheat systems. The VAV concept offers three major efficiency improvements: (1) it reduces or eliminates reheat, (2) it minimizes fan power, and (3) it improves and helps with the minimization of drafts/excess ventilation associated with constant volume systems.

Air Handling Unit Monitoring Plan

Air-Handling Unit Monitoring Plan

Building Name:	ABC Bank Building
Building Location:	123 4th Ave., Seattle, WA 99111
Date:	April 3, 2007
Planned Start Date/Time:	5/1/07 TBD
Planned End Date/Time:	5/15/07 TBD

Re-Tuning Technician Name:	John Doe, McDonalds Control Services
Contact Information:	(509) 555-5555; john.doe@mcs.com
Planned Measurement Period (hours, days or weeks)	2 weeks
Measurement Interval (seconds, minutes, or hours):	30 minutes

Floor:	1
Equipment Name:	AHU-1

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planed Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
OAT1	Outdoor air temperature					Degrees F
MAT1	Mixed air temperature					Degrees F
RAT1	Return air temperature					Degrees F
DAT1	Discharge air temperature					Degrees F
DATSP1	Discharge air temperature set point					Degrees F
PDIST1	Discharge Static Press					in. w.c.
MADamper1	Mixed air damper position					% open
Fan1	Fan status					on/off
Fan Speed1	Fan speed					rpm
CWV%1	Chilled water valve position					% open
HWV%1	Hot water valve position					% open
MODE1	Occupancy mode					Occupied/ Unoccupied

05 Pre-Re-Tuning - SDVAV, Slide 9

- Let's revisit the monitoring plan and use ECAM to analyze trend data.
- Key conditions to look for while analyzing the charts are
    - Unoccupied or 24/7 operation
    - Unoccupied hour setback
    - Lower or higher than expected supply air temperature
    - Excessive outdoor air intake during occupied periods or during pre-cooling periods
    - Excessive outdoor air is not wanted or needed (morning warm-up, morning cool-down, occupied periods) when economizer is turned off or unoccupied periods when air-handling unit is turned on to maintain minimum setback temperatures in the zone
    - Significant reheat during summer/cooling season
    - If VAV, monitor fan speed
    - Higher than normal static pressure
    - Discharge temperature and discharge static pressure resets
    - Economizer not used or not working properly.
    - Simultaneous heating and cooling.

- Typical faults found in a single-duct VAV air-handling unit are night/weekend operations, static pressure set point and resets, supply/discharge temperature set point and resets, minimum outdoor air intake and economizer operation.

Night and Weekend Temperature Setback and Supply-Fan Cycling

- Purpose: Determine whether night and weekend temperature setback is being used

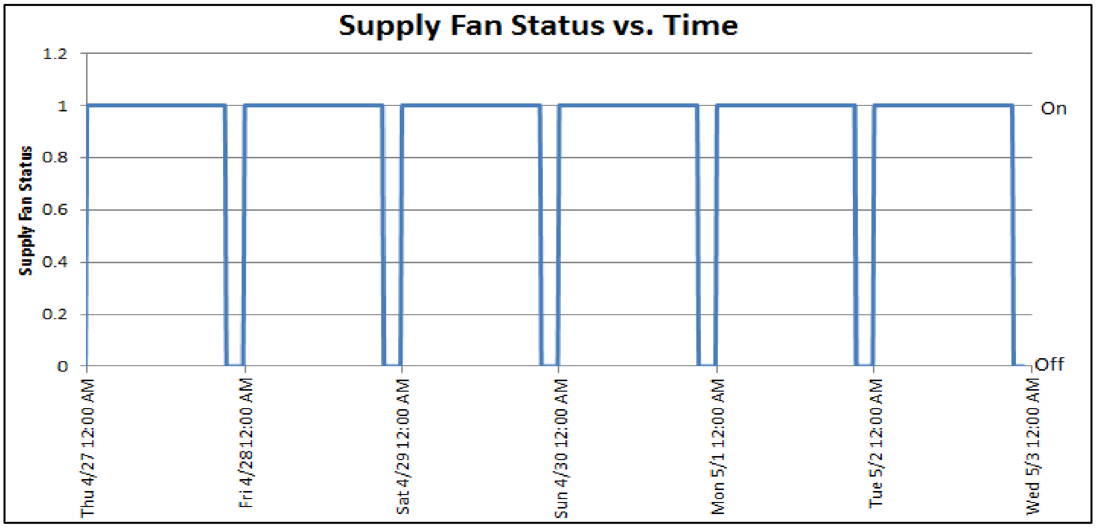
05 Pre-Re-Tuning - SDVAV, Slide 10

Approach:

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

Potential issues to identify include no night, weekend and/or holiday setback for heating and cooling and excessive supply-fan cycling.

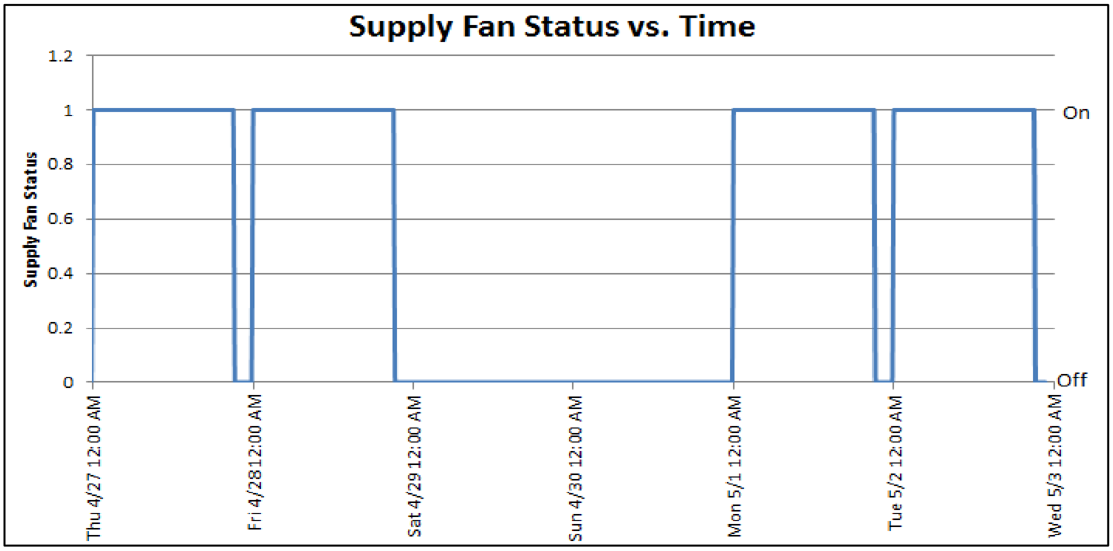
Night and Weekend Temperature Setback and Supply-Fan Cycling: Example Graph



05 Pre-Re-Tuning - SDVAV, Slide 11

- Ask the class what the graph tells them.
- In the schedule being used, the time difference between On and Off is very small. This may be OK, but you may want to increase the time difference.
- There is no weekend setback.

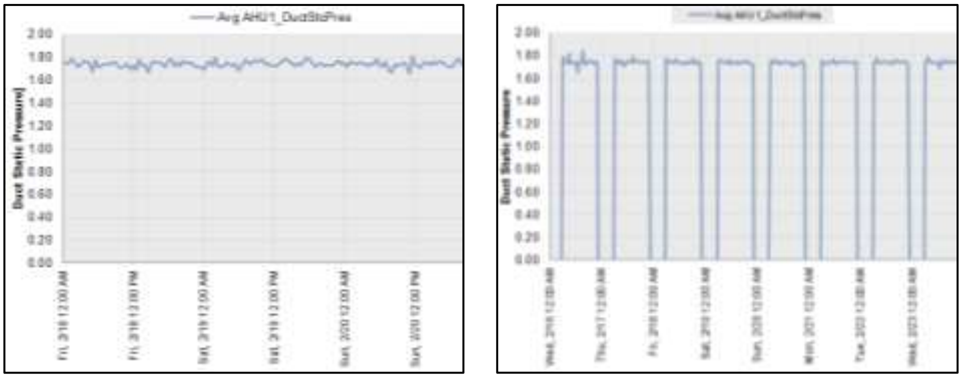
Night and Weekend Temperature Setback and Supply-Fan Cycling: Example Graph



05 Pre-Re-Tuning - SDVAV, Slide 12

Controls are being used more effectively in this graph. There is longer night setback and weekend setback in place.

Night and Weekend Supply-Fan Cycling: Example Graphs



05 Pre-Re-Tuning - SDVAV, Slide 13

- In the slide on the left, static pressure is constantly fluctuating, and there is no night or weekend setback.
- In the slide on the right, night setback is in place.
- Note that static pressure is another point to trend to determine occupancy scheduling.

Re-Tuning Opportunities for SDVAV AHU

- Enable unoccupied mode and night setback control
- Shut off units at night and on weekends
- Turn off heating systems (zone & fan reheat) during summer
- Turn off systems during unoccupied hours
- Slow down systems during unoccupied/lightly occupied hours

05 Pre-Re-Tuning – SDVAV, Slide 14

- Shut off systems on holidays too.
- During the summer when reheat system is shut off, room comfort may be maintained by increasing discharge 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.
- Determine zone temperature setback values that allow for building to cool down during the heating season or warm up during the cooling season, without impacting the building from the stand point of freezing pipes/fire safety sprinkler systems during the heating season, or impacting the ability to recover from setback after a long weekend or extreme weather event. This may require several attempts to fine-tune (re-tune) this. Use of routines like "optimal start" is helpful in this regard.
- To ensure the controls for setback recovery, use zone temperature sensors that represent the space being served (perimeter/interior).

Static Pressure Operations and VAV Box Dampers

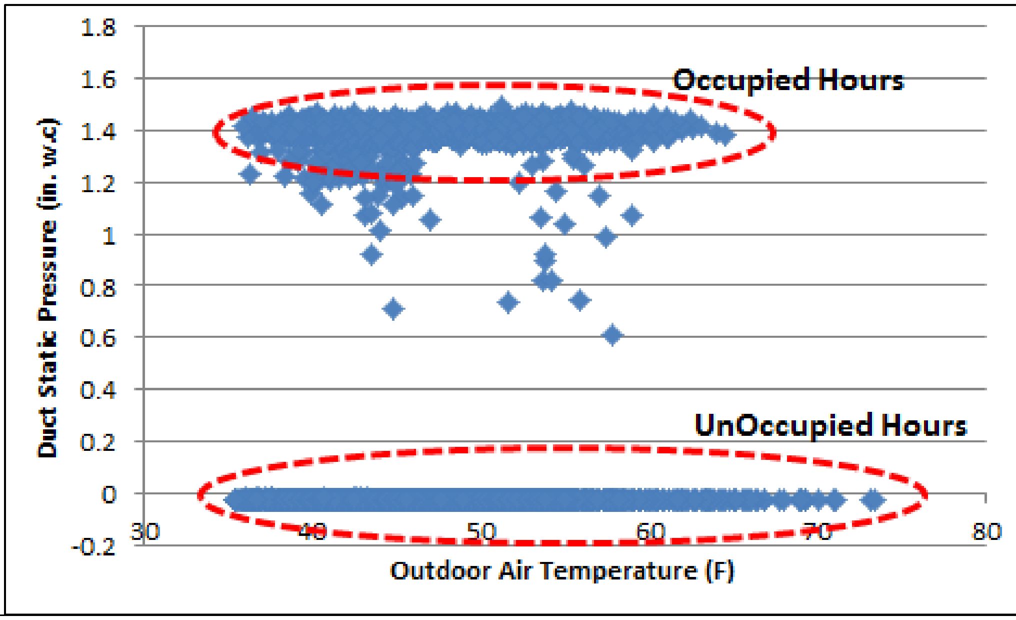
- Purpose: Determine whether static pressure set point is too high or too low
- Approach: For each air handler, review a plot of the damper positions of all VAV units vs. time

05 Pre-Re-Tuning – SDVAV, Slide 15

Look for situations where:

- Most VAV box dampers are nearly closed during cooling—static pressure is too high; the zone temperatures may also be reading excessively low.
- Several VAV boxes on an air handler have dampers fully open—static pressure is too low and/or VAV boxes are not able to meet zone loads (starved boxes); the zone temperatures may also be reading excessively high.
- Dampers aren't modulating as conditions change—VAV boxes are not being controlled or are not responding to control signals.
- Excessively low or high zone temperatures could also be related to excessively low or high discharge temperatures.

STATIC PRESSURE: EXAMPLE GRAPH



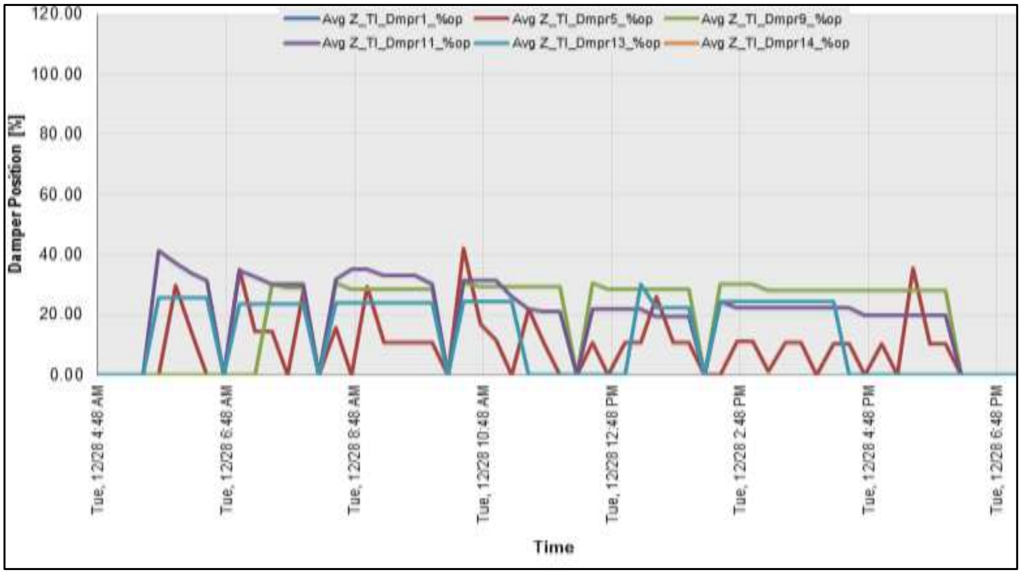
05 PRE-RE-TUNING – SDVAV, SLIDE 16

Constant static pressure set point during occupied hours (at 1.4 in. w.c.)—is this OK? Maybe.

If it is trying to achieve constant set point, loop tuning might be needed, because the static pressure should be able to maintain tighter threshold to the set point.

Look for opportunities to reset static pressure by zone dampers.

Static Pressure: Example Graph



Notes:

05 Pre-Re-Tuning – SDVAV, Slide 17

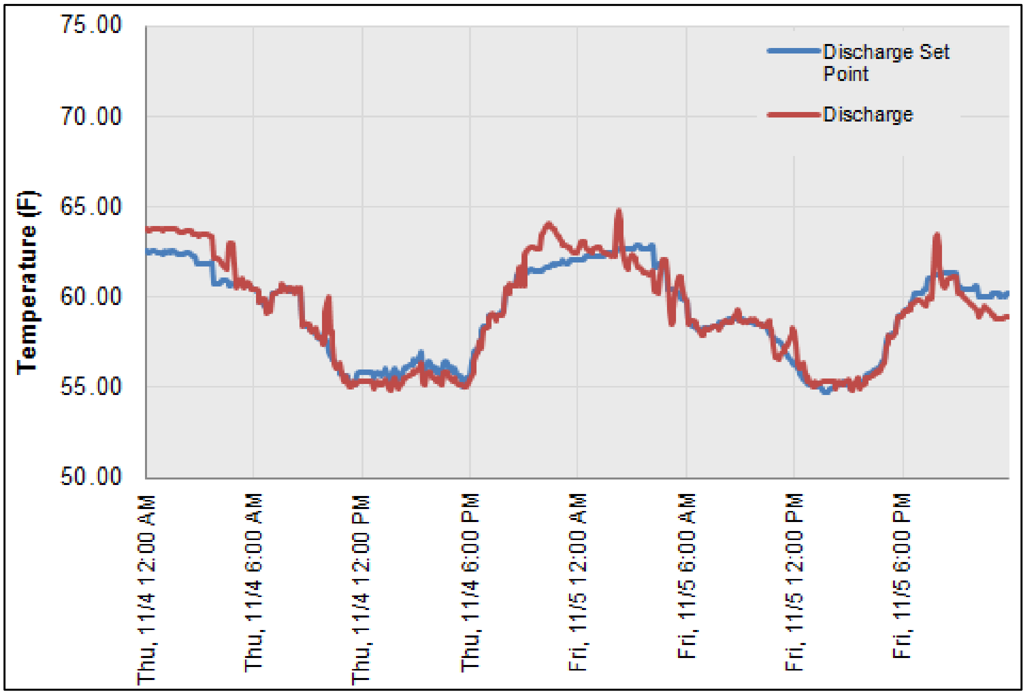
- All of the dampers are at less than 40 % open.
- The static pressure set point may be higher than required.
- If this goes with the previous graph that plots the static pressure at 1.4 inches over various outdoor air temperatures, it could be that during the cooler outdoor air temperatures (no cooling load), that there is excess static pressure.

AIR HANDLER DISCHARGE AIR TEMPERATURES	NOTES:
▶ PURPOSE: ○ DETERMINE WHETHER DISCHARGE AIR TEMPERATURES ARE MAINTAINED RELATIVELY STABLE ○ DETERMINE IF THE DISCHARGE AIR TEMPERATURES ARE TOO COOL OR TOO WARM ▶ APPROACH: REVIEW DISCHARGE AIR TEMPERATURES FOR THE AIR HANDLERS ▶ POTENTIAL ISSUES TO IDENTIFY	

05 PRE-RE-TUNING – SDVAV, SLIDE 18

- 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 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.
- Issues to identify: Discharge air temperature not meeting discharge air set point; unusually unsteady discharge air temperatures; reset not being used for discharge air set point; discharge air set points too high or too low.

Air Handler Discharge Air Temperatures: Example Graph



05 Pre-Re-Tuning – SDVAV, Slide 19

- This graph shows discharge air temperature and discharge air temperature set point vs. time (3 days).
- This graph reveals that reset schedule for set point is in place. There is some fluctuation, so some loop tuning might be appropriate, but this mostly looks good.
- The discharge temperature reset is based upon some type of feedback from the zones/spaces being served. Several feedback strategies can be employed. This can include a discharge temperature reset based upon outside air temperature, return air temperature, one or more zone/space temperatures, one or more terminal box control devices (reheat coils) or one or more zone temperature versus zone set point error deviation algorithms. The simplest algorithms to implement are ones based upon one input (outside air, return air or zone/space temperature), with a corresponding output based upon the change to the input. This generally is a warmer discharge temperature set point, in response to a colder input. A more complex algorithm will use several zone temperatures or several zone reheat valve commands or several zone error deviation values, to calculate a set point that more accurately reflects true space conditions.

MINIMUM OUTDOOR AIR OPERATIONS

PURPOSE:

- DETERMINE IF SUFFICIENT OUTDOOR AIR IS BEING SUPPLIED FOR VENTILATION
- DETERMINE IF MORE OUTSIDE AIR THAN IS NEEDED IS BEING BROUGHT IN
- DETERMINE IF OUTDOOR AIR DAMPERS CLOSE APPROPRIATELY

05 PRE-RE-TUNING – SDVAV, SLIDE 20

- Determine if too much (greater than required for ventilation, which is generally around 10% to 20% supply air flow rate) outdoor air is being brought in—for example, when outdoor air temperature is < 40°F or > 70°F or when zones are unoccupied
- Outdoor air dampers should close during night and weekend setback and during morning startup mode.
- Approach: Review minimum outdoor air operations.

MINIMUM OUTDOOR AIR OPERATIONS (CONTINUED)

APPROACH:

- FOR EACH AIR-SIDE ECONOMIZER, REVIEW PLOTS OF
  - OUTDOOR AIR FRACTION VS. TIME
  - OUTDOOR AIR DAMPER SIGNAL AND OCCUPANCY MODE VS. TIME
  - OUTDOOR AIR FRACTION VS. FAN SPEED (IF AVAILABLE)

05 PRE-RE-TUNING – SDVAV, SLIDE 21

- Determine if outdoor air fraction is more than the minimum outdoor air fraction when the system is not economizing.
- Determine if outdoor air ventilation is being provided when the building is unoccupied and ventilation is not required for some other reason.
- If outdoor air fraction and supply fan speed are tracking each other, then this is an indication of return air problems.

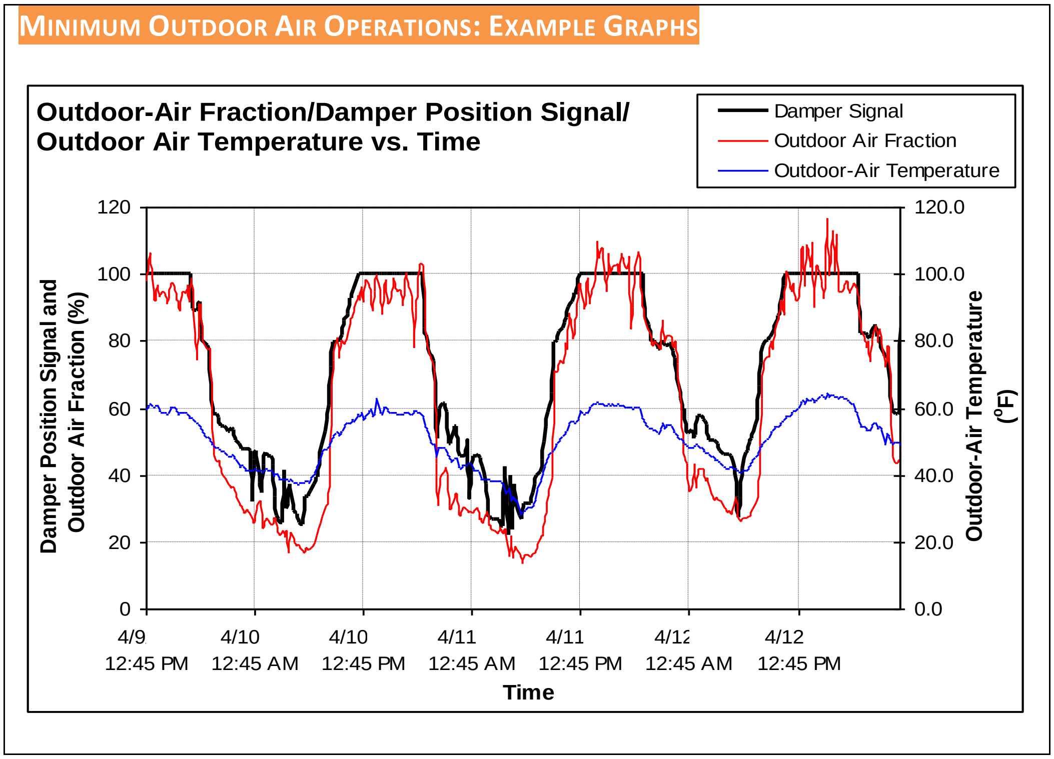
Minimum Outdoor Air Operations (continued)

Potential issues to identify:

- Insufficient outdoor air ventilation provided
- Too much outdoor air ventilation provided

05 Pre-Re-Tuning – SDVAV, Slide 22

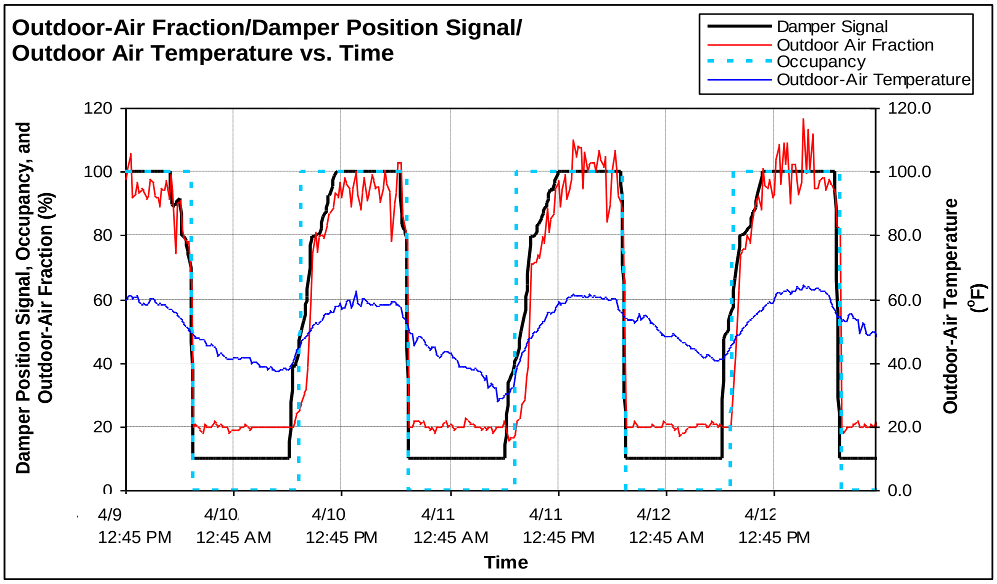
- Insufficient outdoor air ventilation provided—minimum outdoor air fraction is too low.
- Too much outdoor air ventilation provided when the air handler is not economizing or during unoccupied times (nights and weekends, during setback).
- Return air damper or return fan speed control problems.



05 PRE-RE-TUNING – SDVAV, SLIDE 23

- This graph shows outdoor-air fraction, outdoor air temperature, and damper position vs. time. This building is occupied 24/7.
- Damper position is not true outdoor-air fraction. Although the economizer is operating correctly, 20% damper position is NOT 20% outdoor air.

Minimum Outdoor Air Operations: Example Graphs (continued)



05 Pre-Re-Tuning – SDVAV, Slide 24

- This graph plots outdoor-air fraction, outdoor air temperature, and damper position vs. time for a building that is occupied 12 hours per day.
- It also shows that occupancy scheduling is in place and working because the damper falls to a minimum position. The outdoor air temperature is graphed between 35°F and 65°F degrees, which is the ideal range for an economizer if dry bulb temperature is used. In humid regions, use of enthalpy-based economizer cycle may be appropriate.

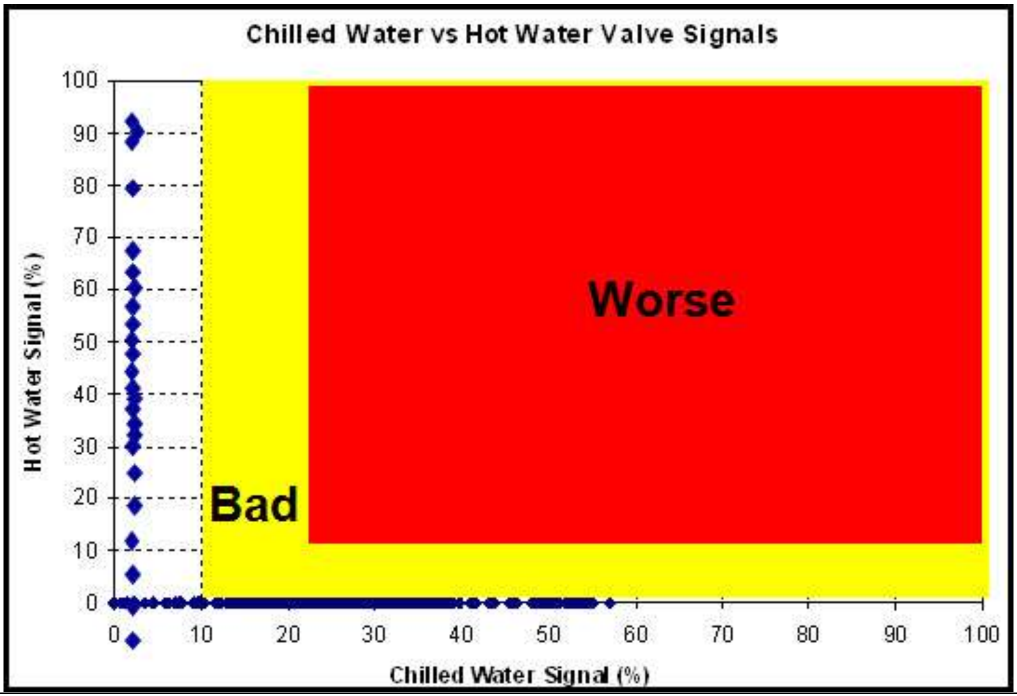
OUTDOOR AIR LOCKOUTS FOR HEATING & COOLING

- PURPOSE: DETERMINE IF THE OUTDOOR AIR LOCKOUTS FOR HEATING AND COOLING ARE SET TO REASONABLE VALUES
- APPROACH: ANALYZE TREND GRAPHS

05 PRE-RE-TUNING – SDVAV, SLIDE 25

- Use plots of heating and cooling outdoor air lockout set points vs. time to determine if the lockouts are set backwards—cooling lockout is lower than the heating lockout. This is a common finding.
- Use plots of heating and cooling valve positions to determine if heating and cooling of the air stream is taking place at the same time.
- Potential issues to identify: Air handler heating and cooling coils operating simultaneously; heating and cooling lockouts possibly overlapping (you will need to confirm in control code settings during onsite re-tuning); unreasonable values set for heating and cooling lockouts.
- Another potential cause for simultaneous heating and cooling is failed control valves (heating and/or cooling coils). If one or both control valves have failed such that tempered water is leaking through the coil (heating coil or cooling coil), the lockouts will often be overlapped to the point of having no influence. This is done so the problem(s) can be "masked" to address comfort problems that resulted from failed control valves.
- Another cause for simultaneous heating and cooling is tight dead bands or no dead bands for the discharge air temperature control loops between heating and cooling functions. Dead bands (when properly set) provide for energy savings and loop stability.

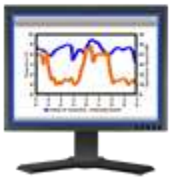
Outdoor Air Lockouts for Heating & Cooling: Example Graph



Notes:

05 Pre-Re-Tuning – SDVAV, Slide 26

- Air handler heating vs. cooling valve positions.
- If heating and cooling are occurring at the same time, the further away from 0, the worse it is.
- Hand out AHU O&M Checklist (in Appendix A).



Chapter 6: Economizer Operations: Pre-Re-Tuning and Re-Tuning

INSTRUCTOR GUIDANCE

TIME: 30 MINUTES

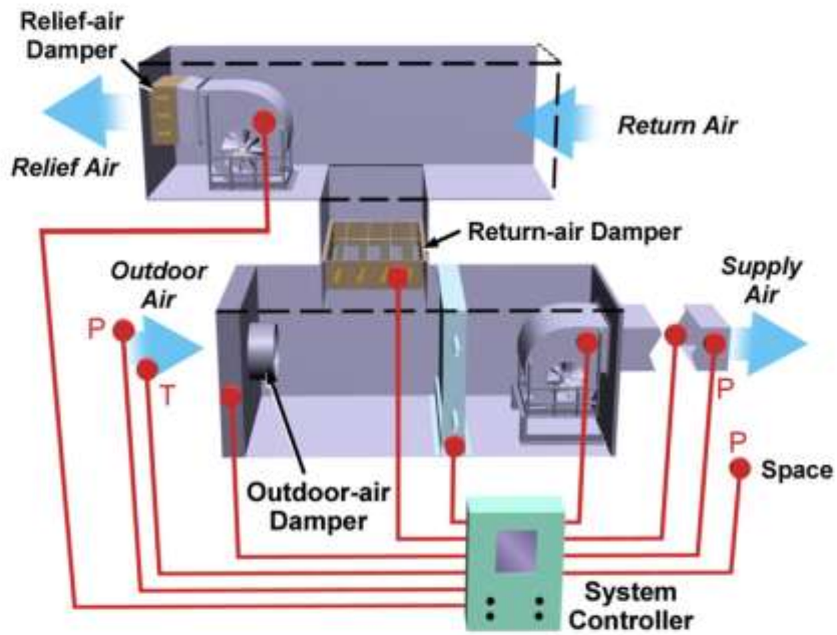
LESSON GOAL: UNDERSTAND THE PRE-RE-TUNING AND RE-TUNING PROCESS FOR THE ECONOMIZER

LEARNING OBJECTIVES:

- UNDERSTAND BASIC ECONOMIZER OPERATIONS
- UNDERSTAND THE POINTS TO PLOT FOR ECONOMIZERS
- GENERATE ECONOMIZER TREND GRAPHS
- ANALYZE ECONOMIZER TREND GRAPHS
- RE-TUNE THE ECONOMIZER

Economizer Fundamentals

The Basics of Airside Economizers



06 Pre-Re-Tuning – Economizer Operations, Slide 3

- Airside Economizer: "A duct-and-damper arrangement and automatic control system that, together, allow a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling during mild or cold weather." (*ASHRAE Standard 90.1-2004*)
- Airside economizers simply use air source energy from outside the building to cool the building or to supplement the mechanical cooling system. Typically, an air source system will use duct work on a central air handling unit or on a packaged rooftop unit.
- Normally, automatic controls will operate the economizer cycle.
- The relief damper and relief fan can be problematic (provides another path for outside air to enter the mixing plenum if the relief dampers fail).
- The picture above is often accurate. This can be problematic during cold weather, in that cold air will stay toward the bottom of the duct (heavier/denser mass) and will not mix very well with the warm return air which is lighter and tends to say high. The result is the mixed air sensor does not "see" a good mixing effect of two diverse air streams in extremely cold weather. This can lead to a lot of problems for the mixed air control (frozen coils, wrong temperature sensing, etc).

Air Handler Economizer

- **Control vendor specifications:**
- **ECONOMIZER DRY-BULB SWITCHOVER:** When the shared outside air temperature is below the switchover set point, the economizer will be enabled. When the shared outside air temperature rises above the switchover set point plus a differential, the economizer will be disabled
- **DISCHARGE-AIR CONTROL:** the mixed-air dampers, and the cooling valve will modulate in sequence to maintain the discharge air temperature at set point

06 Pre-Re-Tuning – Economizer Operations, Slide 4

- These are the specifications from a vendor manual.
- The reality is:
  - Airside economizing uses unconditioned outside air to cool (or heat) a space.
  - There are two air streams for supply air: outside and return.
  - Dampers need to sequence together to mix and balance air flow streams to match needs of air-handler discharge conditions.
  - As long as the outside air is cooler than return, it should be used even if mechanical cooling is required. In humid climates, when enthalpy-based economizers are not used, use economizers when outdoor-air is between 5°F and 10°F below return air temperature.

Air Handler Economizer

- Which air stream is most efficient to use at a specific condition?
  - Dry-bulb condition cooling comparison
  - Building is heating, use return air

06 Pre-Re-Tuning – Economizer Operations, Slide 5

- Which air stream should you choose?
- If outside air is cooler than return air, use it for most dry climates, even if you have to run some additional cooling.
- If the air handler or rooftop unit is in heating mode, use the return air. Do not use outside air when preheating or during unoccupied fan heating operations. During unoccupied fan cooling operations, use outside air, if it has colder (lower heat content) than the return air.

Economizer Operation—What to Look For

► Purpose: Determine if air-side economizers are operating properly

06 Pre-Re-Tuning – Economizer Operations, Slide 6

- Do economizers open, close, and/or modulate appropriately given the conditions?
- At what temperature do they operate 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?
- Does the cooling coil operate (chilled water flow) during economizing and outside air temperatures < 55°F? Normally, it should not.

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

06 PRE-RE-TUNING – ECONOMIZER OPERATIONS, SLIDE 7

- 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 economizing under favorable conditions (outdoor air temperature is lower than discharge set point) and cooling coil (chilled water flow) operating.
- Look for outdoor air damper not closing to minimum position for freeze prevention when outdoor temperature is less than about 40°F.
- Look for mixed air temperature lower than 40°F in which case the outdoor air dampers should be completely closed.

ECONOMIZER OPERATION (CONTINUED)

- POTENTIAL ISSUES TO IDENTIFY:
    - INCORRECT ECONOMIZER OPERATION
    - NUMEROUS CAUSES OF INCORRECT OPERATION (IDENTIFIED LATER DURING ONSITE WORK)

06 PRE-RE-TUNING – ECONOMIZER OPERATIONS, SLIDE 8

- Incorrect control strategy
- Stuck dampers
- Disconnected or damaged linkages
- Failed actuator or poorly calibrated actuator
- Failed, uncalibrated, or poorly calibrated sensors
- Obstructions (such as 2 X 4) in damper
- Missing damper blade seals (air leakage, even with dampers closed)
- Short-circuited air stream (exhaust/relief sucked back into outside air intake).

WHY ECONOMIZERS FAIL AND INCREASE ENERGY USE

JAMMED/FROZEN DAMPER

WIRED POORLY

DISCONNECTED DAMPER

06 PRE-RE-TUNING – ECONOMIZER OPERATIONS, SLIDE 9

Some reasons for failure

- Jammed or frozen outside air damper
- Broken and/or disconnected linkage
- Nonfunctioning actuator or disconnected wire
- Malfunctioning outside air/return-air temperature sensor
- Malfunctioning controller
- Faulty control settings
- Installed wrong or wired incorrectly.

Rooftop Units with Economizers

06 Pre-Re-Tuning – Economizer Operations, Slide 10

- Packaged rooftop units with economizers are often neglected, hard to access, or installed poorly.
- The top two photos show equipment too close together; economizers are sucking in hot air.
- Bottom left – economizer difficult to service; may be sucking in vehicle exhaust.
- Bottom right – exhaust fan is discharging into economizer.
- These may be design issues and may require capital to correct.

Another Packaged Rooftop Unit Example

06 Pre-Re-Tuning – Economizer Operations, Slide 11

- This poorly designed packaged rooftop unit with economizer is installed next to heat source from condenser.
- Again, this may be a design issue and may require capital to correct.

Another Packaged Rooftop Unit Example

06 Pre-Re-Tuning – Economizer Operations, Slide 12

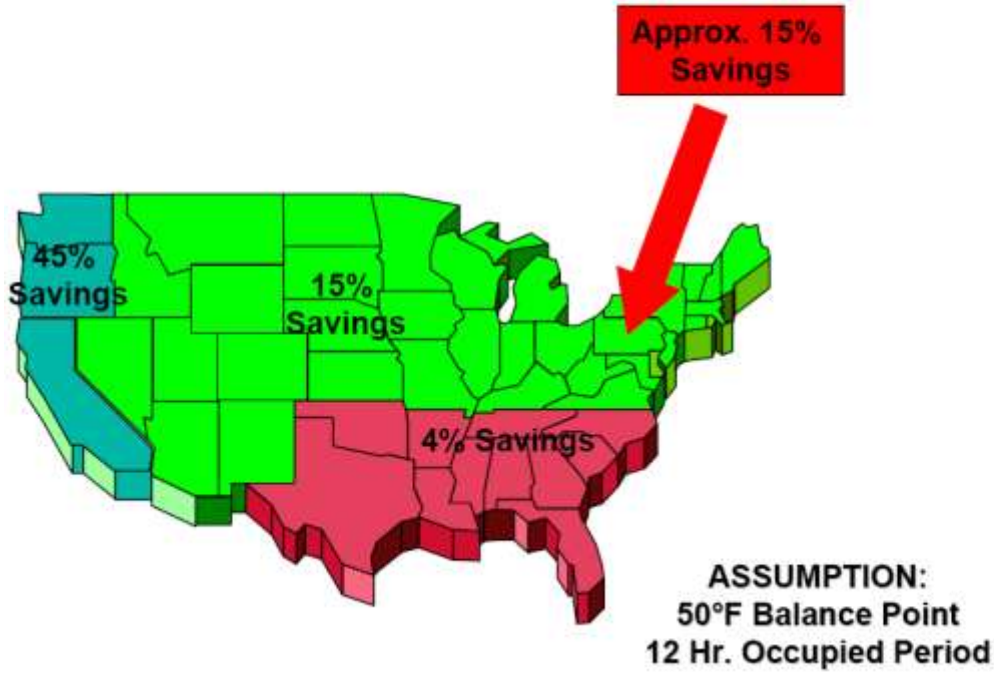
- These photos were taken at a newly constructed restaurant soon **after** a visit by the HVAC service contractor. The roof was littered with old, filthy filters and bent, discarded “bird screens” intended to protect the unit’s outdoor air opening.
- Close inspection revealed several instances of missing filters and filthy cooling coils.
- Rooftop unit (RTU) equipment often doesn’t get enough maintenance.

Another Packaged Rooftop Unit Example

06 Pre-Re-Tuning – Economizer Operations, Slide 13

- These pictures show brand-new RTU equipment on a building in 2008.
- Notice the outside air intake is either right on top of the exhaust or next to the exhaust on the unit.
- The bottom right picture shows an exhaust damper against a wall.
- Adjacent to the wall, next to the exhaust, is the outside air intake for bringing fresh air into the building.
- This is not a good design and may not work properly unless ductwork is added to the unit to exhaust the air properly, which will require capital.

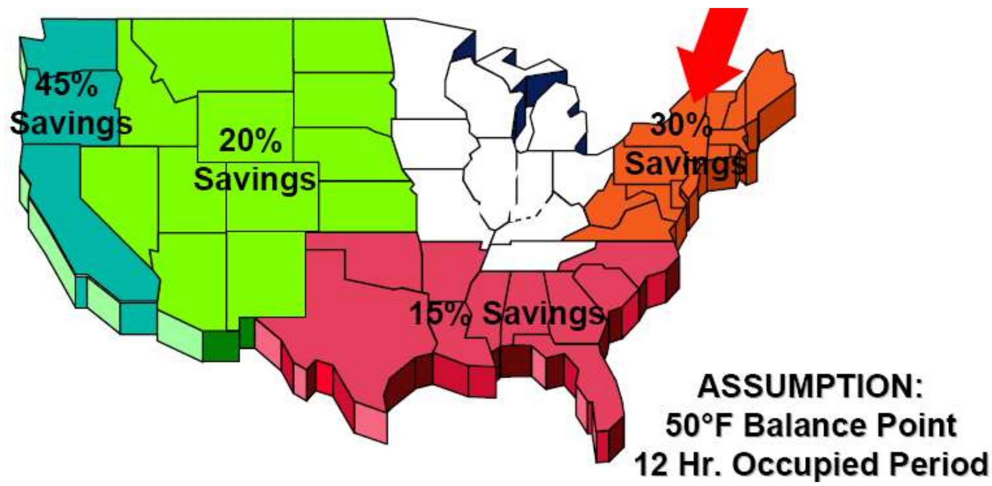
POTENTIAL ECONOMIZER SAVINGS FROM ENTHALPY CONTROL



06 PRE-RE-TUNING – ECONOMIZER OPERATIONS, SLIDE 14

- The map assumes 50°F balance point and a 12-hour occupied period.
- This shows savings across the United States using outdoor enthalpy control.

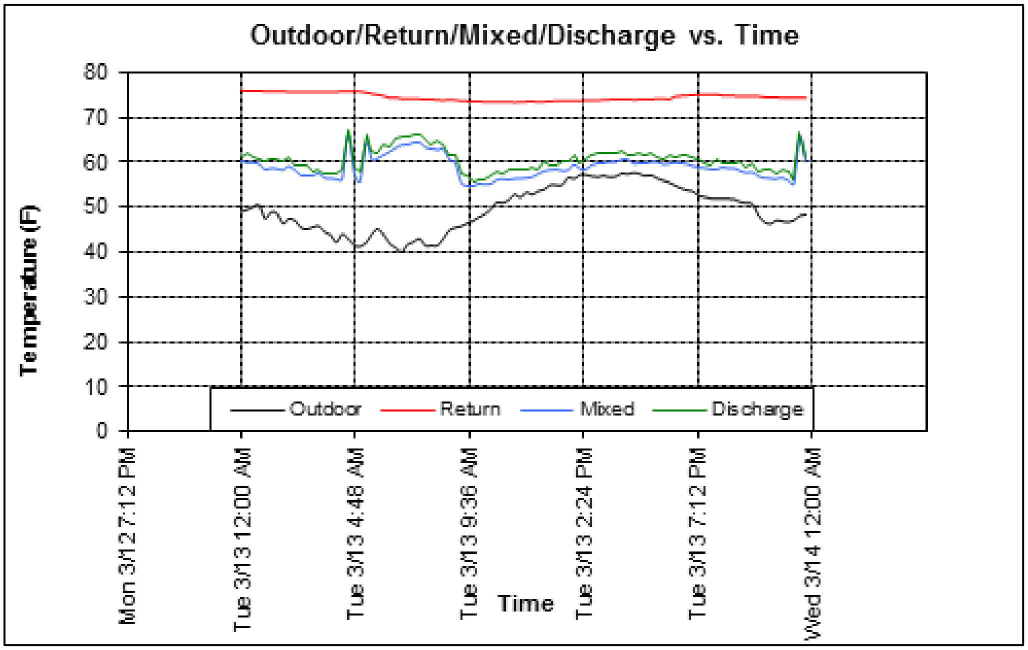
POTENTIAL ECONOMIZER SAVINGS FROM DIFFERENTIAL ENTHALPY CONTROL



06 PRE-RE-TUNING – ECONOMIZER OPERATIONS, SLIDE 15

- This shows savings across the United States using differential (outdoor vs. return) enthalpy control—uses the most efficient airstream.

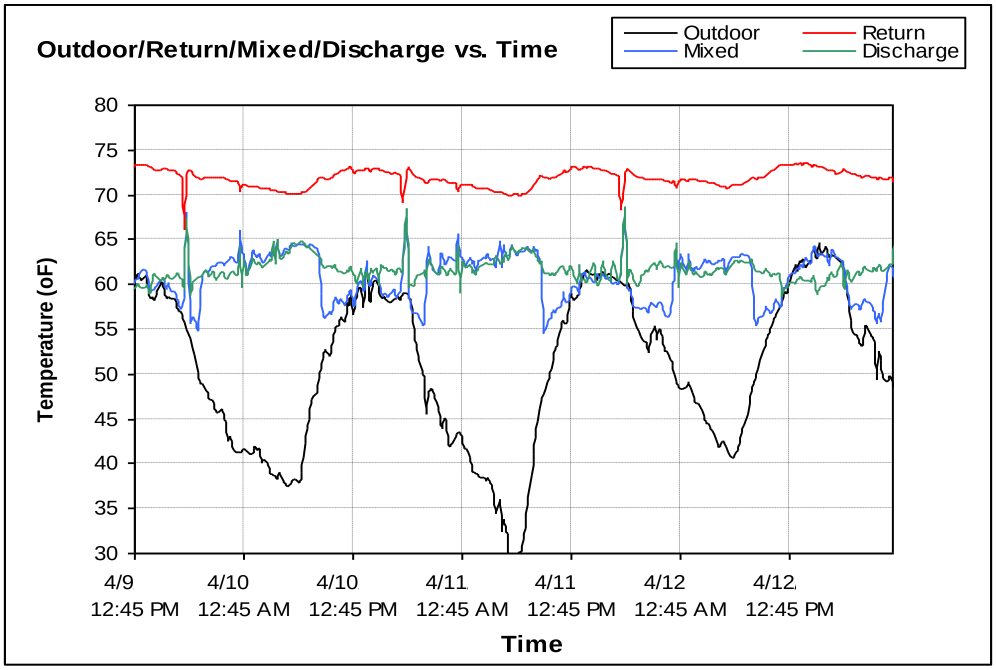
ECONOMIZER OPERATION: EXAMPLE GRAPH



06 PRE-RE-TUNING – ECONOMIZER OPERATIONS, SLIDE 16

- This economizer is operating normally.
- The outdoor air temperature is lower than 60°F, which is when an economizer should be used.
- The mixed and discharge air temperature are very close to the same, which says that the damper is modulating to maintain the discharge air set point (or some kind of mixed air set point).

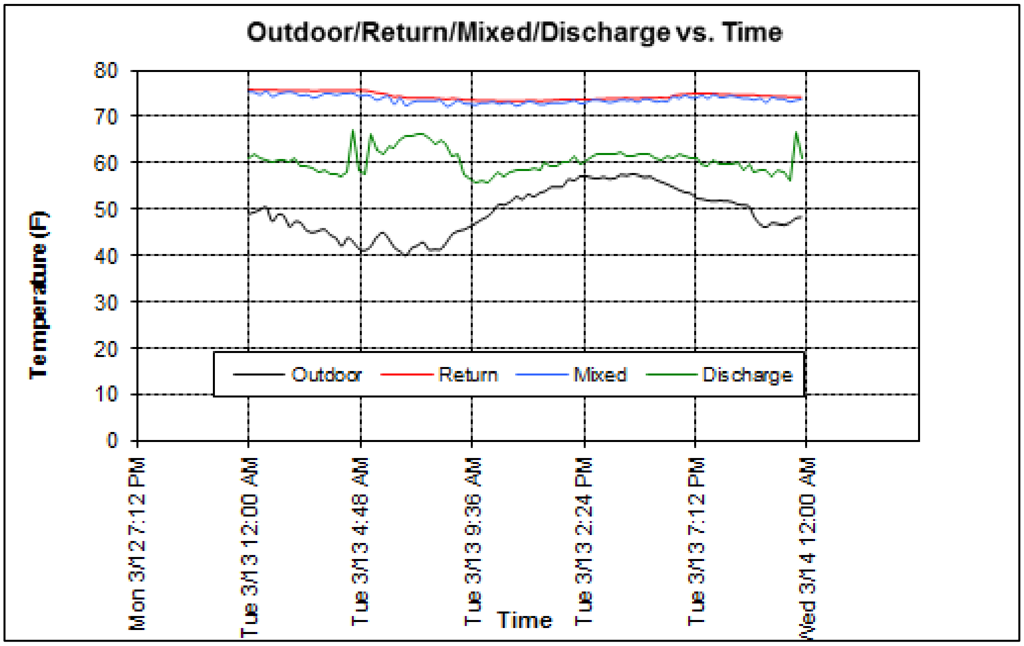
ECONOMIZER OPERATION: EXAMPLE GRAPH



06 PRE-RE-TUNING – ECONOMIZER OPERATIONS, SLIDE 17

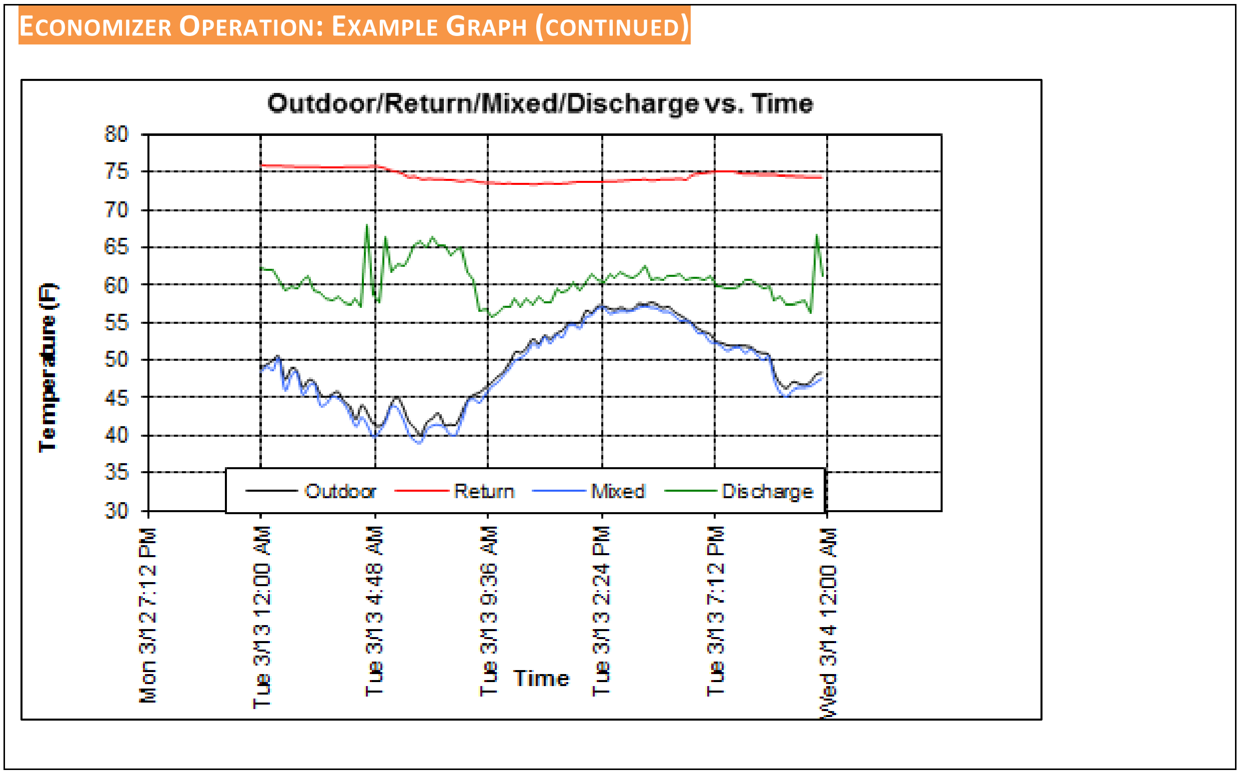
The economizer is operating normally and has no problems.

Economizer Operation: Example Graph (continued)



06 Pre-Re-Tuning – Economizer Operations, Slide 18

- Unlike the previous two graphs, the mixed air temperature is following the return air temperature.
- Both the previous graphs and this one represent the economizer season.
- Note that in this graph, no fresh air is coming into the building (the outdoor air damper is stuck closed).



06 PRE-RE-TUNING – ECONOMIZER OPERATIONS, SLIDE 19

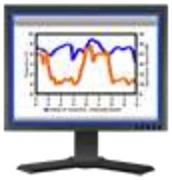
- Note the mixed air temperature is running down with the outdoor air temperature.
- The likely cause is a stuck outdoor air damper—heat is almost certainly being wasted.

ECONOMIZER OPERATION TIPS

- SET ECONOMIZER OPERATING RANGE AS WIDE AS POSSIBLE
- USE ECONOMIZER TO CONTROL DISCHARGE AIR TEMPERATURE DIRECTLY WHEN OUTSIDE AIR TEMPERATURE IS LOWER THAN THE DISCHARGE AIR SET POINT
- AN AVERAGING TEMPERATURE SENSOR SHOULD BE USED FOR THE MIXED AIR TEMPERATURE MEASUREMENT

06 PRE-RE-TUNING – ECONOMIZER OPERATIONS, SLIDE 20

- Economizer range recommendations:
  - Between 35°F and 75°F for dry climates
  - Between 35°F and 68°F for normal climates
  - Between 35°F and 65°F for humid climates.
- When outside air temperature is lower than discharge air set point, the chilled water valve should be locked out (fully closed), to avoid damper and valve fighting.
- Most mixing chambers do not achieve complete mixing of the return air and outside air before reaching the cooling coil.



Chapter 7: Terminal Units in Air Distribution System: Pre-Re-Tuning and Re-Tuning

INSTRUCTOR GUIDANCE

TIME: 75 MINUTES

MATERIALS: POWERPOINT SLIDES 07 PRE-RE-TUNING ZONES

LESSON GOAL: UNDERSTAND THE PRE-RE-TUNING AND RE-TUNING PROCESS FOR TERMINAL UNITS

LEARNING OBJECTIVES:

- UNDERSTAND BASIC TERMINAL UNIT OPERATIONS
- UNDERSTAND THE POINTS TO PLOT FOR TERMINAL UNITS
- GENERATE ZONE TREND GRAPHS
- ANALYZE ZONE TREND GRAPHS
- RE-TUNE THE TERMINAL UNITS AND OTHER FACTORS AFFECTING ZONE OPERATIONS

About Terminal Units

- In an HVAC system, a terminal unit (or box) is the unit at the end of a branch duct through which air is transferred or delivered to the conditioned space
- Terminal units are major HVAC components and directly impact comfort and energy costs

07 Pre-Re-Tuning Phase Zones, Slide 2

- Terminal units 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.
- Discharge air temperatures from the air handler (if too low) can also contribute to simultaneous heating and cooling.
- Discharge static pressure from air handler (if too high) can also contribute to extra fan power consumption.

Classification of Terminal Units

- Unit operation
  - Primary air only / induction unit / fan powered
- Primary air inlet
  - Single duct / dual duct
- Discharge 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

07 Pre-Re-Tuning Phase Zones, Slide 3

Note: This optional slide simply lists different types of terminal units. Instructor may modify and add relevant notes or omit.

COMMONLY USED TERMINAL UNITS

- SINGLE-DUCT VARIABLE AIR VOLUME (SDVAV) TERMINAL BOX
- FAN-POWERED UNIT
- DUAL-DUCT
- INDUCTION UNITS

07 PRE-RE-TUNING PHASE ZONES, SLIDE 4

- These are the most commonly used terminal units.
- Single-duct VAV boxes may come with reheat (hot water reheat/electrical reheat; typically used in perimeter zones) or without reheat (typically used in interior zones).
- Fan-powered units may be either parallel or series type.
- Dual-duct units may be either constant air volume or variable air volume.
- Induction units, which are typically used in perimeter zone applications, are designed for floor-mounted under-floor air delivery. They are usually located directly under windows, and may be two pipe or four pipe.

COLLECTING BASIC INFORMATION

GENERAL

- TYPES OF TERMINAL UNITS (FILL IN MATRIX TABLE)
- NUMBER OF EACH TERMINAL UNIT TYPE
- PNEUMATIC OR DIRECT DIGITAL CONTROL (DDC) CONTROL

SPECIFIC (OPTIONAL)

- ANY UNUSUAL GAS CONSUMPTION DURING SUMMER (FROM UTILITY BILL)?
- ANY COLD/HOT SPOT FOR SPECIFIC AREA (FROM OPERATOR INTERVIEW)?

07 PRE-RE-TUNING PHASE ZONES, SLIDE 5

- This is the basic information you need to collect.
- What is "unusual" heating consumption? An example is HVAC gas consumption is more than 10% of cooling during a hot summer.

EXAMPLE MATRIX

	PRESSURE-DEPENDENT (NO FLOW STATION)	PRESSURE-INDEPENDENT (WITH FLOW STATION)
WITH HOT WATER REHEAT	0	34
WITH ELECTRICAL REHEAT	0	0
WITHOUT REHEAT	0	68

07 PRE-RE-TUNING PHASE ZONES, SLIDE 6

- This is an optional slide—it just shows an example matrix for collecting basic information.

Collect 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?

07 Pre-Re-Tuning Phase Zones, Slide 7

- All of the above are candidates for re-tuning.
- "Others?" Determine if there are any dead bands.
- A "dead band" is an area of a signal range or band where no action occurs. The purpose is to prevent oscillation or repeated on/off cycling. A 2^{o}F to 4^{o}F dead band is generally recommended.
- The trainer needs to emphasize that the zones are not capable of heating and cooling at the same time (there is no cooling coil, only a heating coil). The cooling occurred back at the main supply fan cooling coil (which is not part of this training discussion). The cooling is occurring at the main supply fan, either via economizer cooling or mechanical cooling (or both), to maintain a discharge air set point that is either fixed or reset.

TREND DATA COLLECTION AND ANALYSIS OF TERMINAL UNITS

- COLLECT ALL MINIMUM AIR FLOW AND MAXIMUM AIR FLOW SETTINGS FOR PRESSURE-INDEPENDENT UNITS USING THE BUILDING AUTOMATION REPORTING FUNCTION
- COLLECT ALL TERMINAL BOX DAMPER POSITIONS & REHEAT VALVE POSITIONS USING BAS

07 PRE-RE-TUNING PHASE ZONES, SLIDE 8

- The purpose of collecting air flow information is to identify potential for reducing minimum cooling air flow setting.

- The purpose of collecting damper and valve positions is to identify simultaneous heating and cooling.

- Siemens Apogee: use the report function.

  1. Collect the TB setting:

  CLG FLOW MIN Point number 31, *the minimum amount of air in CFM (or LPS) to be supplied to the space in cooling mode.*

  CLG FLOW MAX Point number 32, *the maximum amount of air in CFM (or LPS) to be supplied to the space in cooling mode.*

  2. Take snapshot for the damper position:

  DMPR POS – point 49, Damper command point 48

  VLV COMD point 52, Valve Position point 53.

SELECT ZONES FOR TRENDING

- SELECT ZONES FOR TRENDING (BASED ON OPERATOR'S INPUT & BAS REPORT)
- REFER TO THE ZONE/VAV BOX MONITORING PLAN/TABLE

07 PRE-RE-TUNING PHASE ZONES, SLIDE 9

Zones recommended for trending (see Appendix for more details on setting up trend logs):

- Zones with comfort complaints
- Interior zones with low/light cooling load (e.g., janitor's room or storage room)
- Zones with high minimum air flow setting (e.g., > 35%)
- Perimeter zones with reheat during cooling season
- Office that is no longer fully occupied as originally designed. Examples: Offices converted to storage rooms; a previously fully occupied office space now 10% occupied.

Parameters to Trend

- Trend as many points as possible from the following list:
  - Zone air temperature
  - VAV damper position
  - VAV reheat valve position or stage
  - Zone occupancy mode
  - If possible also trend
    - AHU Discharge air temperature
    - Discharge air temperature after the reheat coil
    - Electrical heater stage
    - Outdoor air temperature

07 Pre-Re-Tuning Phase Zones, Slide 10

- Discharge air temperature (DAT) from air handler unit (AHU).
- If you can't trend DAT after reheat coil (for hot water reheat), trend reheat valve position.
- For electrical reheat boxes, trend heater stage or on/off status.
- Get the outdoor air temperature from the building automation system (BAS).

DATA ANALYSIS

- USE ECAM TO ANALYZE THE COLLECTED DATA
- KEY CONDITIONS TO LOOK FOR WHILE ANALYZING THE CHARTS:
  - NO NIGHT OR WEEKEND SETBACK
  - SIGNIFICANT REHEAT FOR INTERIOR ZONE TERMINAL BOX DURING OCCUPIED HOURS
  - OVERHEATING OR OVERCOOLING
  - SIGNIFICANT REHEAT DURING SUMMER (COOLING SEASON) FOR EXTERIOR ZONE BOX

07 PRE-RE-TUNING PHASE ZONES, SLIDE 11

Additional key conditions to look for are:

- 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/NIGHT SETBACK

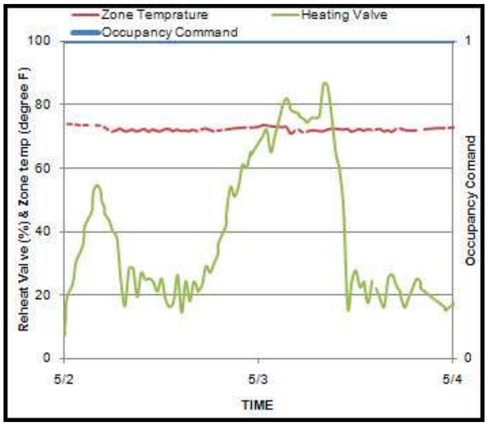
- UNOCCUPIED MODE/NO NIGHTTIME SETBACK FOR TERMINAL BOX
    - DETERMINE WHETHER THE UNOCCUPIED PERIOD IS NOT DEFINED OR THE TIME SCHEDULE IS NOT ENABLED

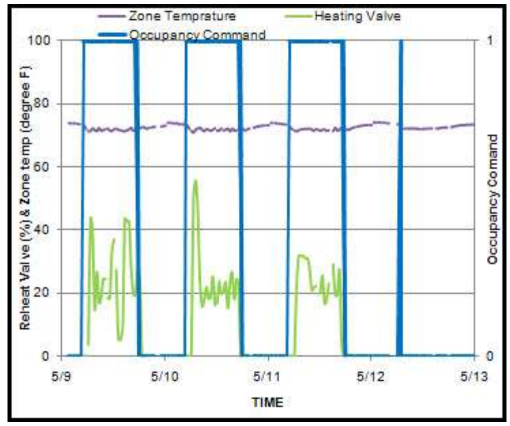
07 PRE-RE-TUNING PHASE ZONES, SLIDE 12

Approach:

- Review the plots of zone occupancy command, heating valve, or damper position vs. time.
- Look for the valve and/or damper position during unoccupied periods.

UNOCCUPIED MODE/NIGHT SETBACK: EXAMPLE





07 PRE-RE-TUNING PHASE ZONES, SLIDE 13

- Occupancy command + valve position.
- In the figure on the left, there is no zone temperature setback. In the figure on the right, occupancy scheduling is clearly in place.
- In the figure on the right, the fact that the zone temperature rises during the unoccupied periods, then drops during the occupied periods, indicates that potential overcooling is occurring (thus having to reheat) during the occupied period.

Re-Tuning Recommendations for Unoccupied and Night Setback

- Enable unoccupied mode and night setback control
- Develop a schedule for each zone

07 Pre-Re-Tuning Phase Zones, Slide 14

To enable unoccupied mode and night setback, you first should develop a schedule for each zone.

- Turning off systems too early in the evening or turning them on too late in the morning will cause comfort problems. Make small changes over time.
- Make sure unoccupied mode is enabled.
- Make sure zone strategy will not allow zone temperature(s) to drop too low/rise too high during the night setback period, without automatically returning the zone and/or air handler serving the zone(s), to the occupied mode to maintain minimum/maximum temperatures in the zone(s).

Reheat for Interior Zone VAV Box

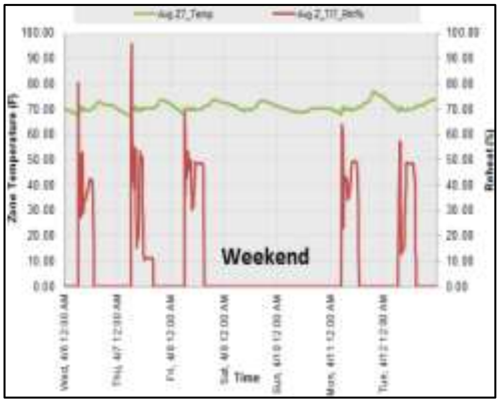
▶ Situation: Minimum air flow setting is too high, leading to excessive reheat

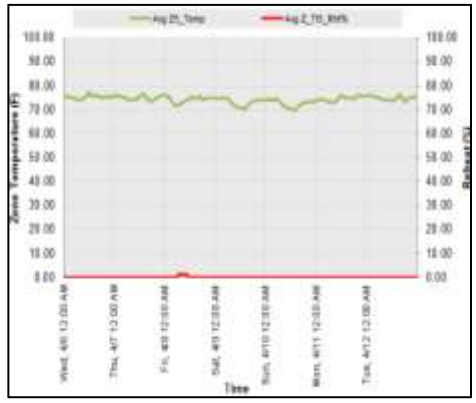
07 Pre-Re-Tuning Phase Zones, Slide 15

Heating typically is not needed for an interior zone office.

- Determine whether the heating valve is open during occupied hours during the summer.
- Review the plots of heating valve vs. time and outdoor air temperature.
- Because some interior zones do not have reheat coils, review status of portable heater use during cooling season. Excess portable heater use in interior zones could be indicative of greater problems (minimum air flow setting too high, discharge air temperature too low, etc).

REHEAT FOR INTERIOR ZONE VAV BOX





07 PRE-RE-TUNING PHASE ZONES, SLIDE 16

In the example on the left, night setback for the terminal unit is in place. However, the minimum air flow set point is too high, and heating is turned on to maintain comfort. The example on the right shows controls being used properly.

Re-Tuning Recommendations for Interior Zone

- Reduce interior zone terminal box minimum air flow setting
  - For example, 5% to 10% of the maximum air flow set point but not lower than 75 CFM/person
- Disable Heating for interior zones in summer (outdoor air temperature > 70°F, for example) to eliminate heating leakage

07 Pre-Re-Tuning Phase Zones, Slide 17

- Disable reheat: terminal unit control or shut off boiler if on for reheating.
- Convert the terminal box to cooling only for interior zone terminal unit permanently.
- In principle, the minimum air flow should be determined based on the zone outdoor air requirement and maximum heating load. Terminal units with conventional control sequences may cause occupant discomfort or waste energy. Terminal units will have significant simultaneous heating and cooling, and air handlers will consume more fan power if the minimum air flow is more than required. On the other hand, air-conditioned space will have indoor air quality problems with less air circulation if the minimum air flow is less than required.

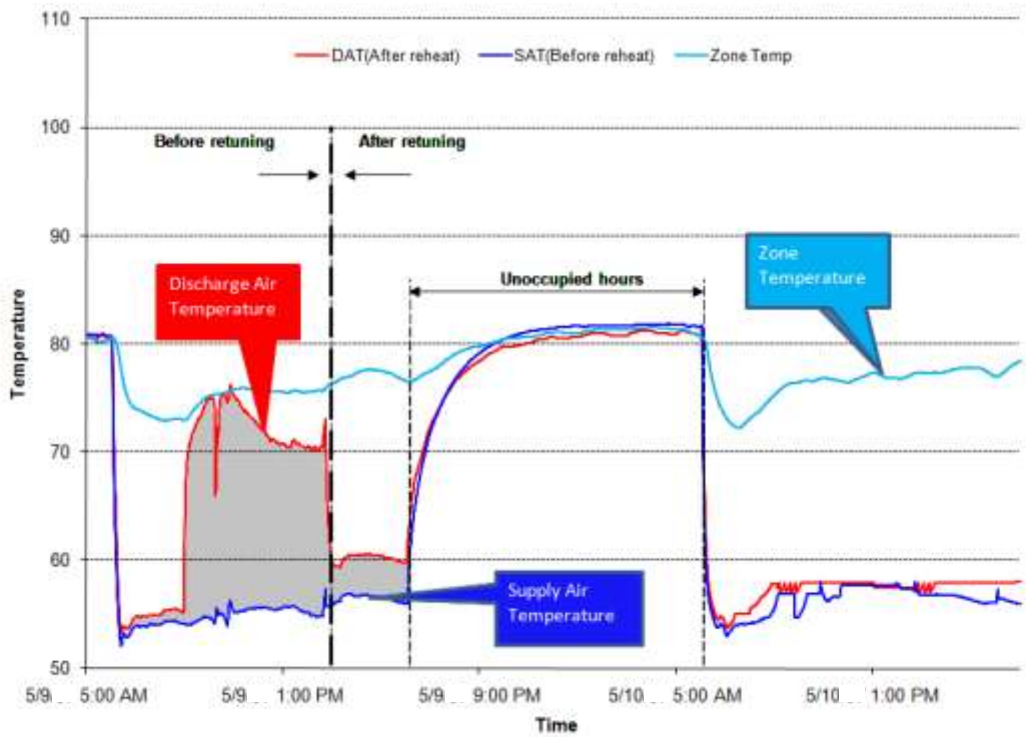
VAV Terminal Unit Re-Tuning Example for Interior Zone

- Office building
- Single-duct VAV units with hot water reheat
- Re-tuning measure: Reduce the cooling minimum

07 Pre-Re-Tuning Phase Zones, Slide 18

- Before re-tuning: Cooling MAX=387 cfm, Cooling MIN=200 cfm
- After re-tuning: Cooling MAX=387 cfm, although 10% of maximum is 39 cfm, the minimum should be at 75 cfm (assuming one person office), if the office has more than one occupant, the minimum should be increased appropriately.

VAV Terminal Unit Re-Tuning Example for Interior Zone



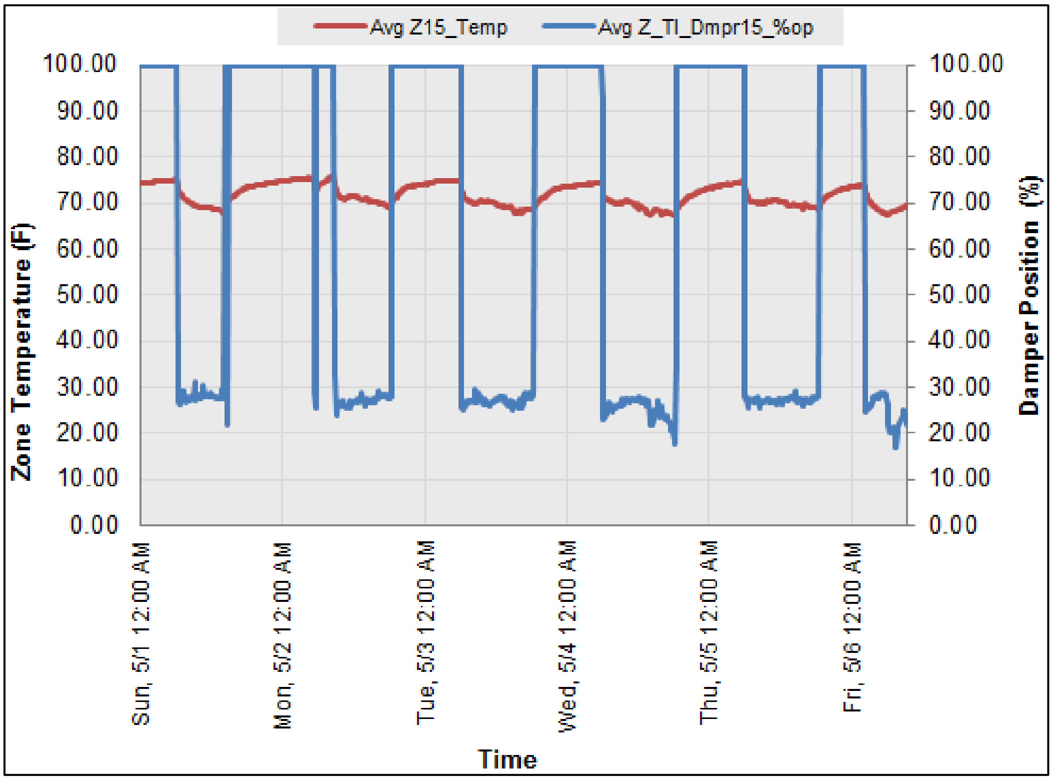
07 Pre-Re-Tuning Phase Zones, Slide 19

Reset the minimum air flow set point to minimize reheat.

- This graph shows the supply air temperature (before reheat coil) and the discharge air temperature (after reheat coil) for one interior zone terminal box.
- Both discharge air temperature and supply air temperature were trended. Significant reheat energy consumption (gray zone), can be found before re-tuning.
- After retuning, the gray zone is greatly diminished.

Overcooling Example

▶ Case 1: The minimum air flow is too high



07 Pre-Re-Tuning Phase Zones, Slide 20

The terminal box damper is forced open to meet the minimum air flow requirement, although the room temperature set point is satisfied.

Note: This is a cooling-only terminal unit for the interior zone. Could it be that the cooling minimum is too high and duct static pressure is not enough? The box is wide open to maintain the higher minimum flow set point.

Note: Could it be a failure with the terminal box air flow sensor (failed to indicate any flow or low flow, when in fact there could be too much air flow)? This could be caused by an air flow anomaly (disconnected or plugged sensing lines, disconnected or improperly wired air flow sensor, air flow sensor failure, etc.).

Simultaneous Heating and Cooling for Exterior Zone Terminal Units

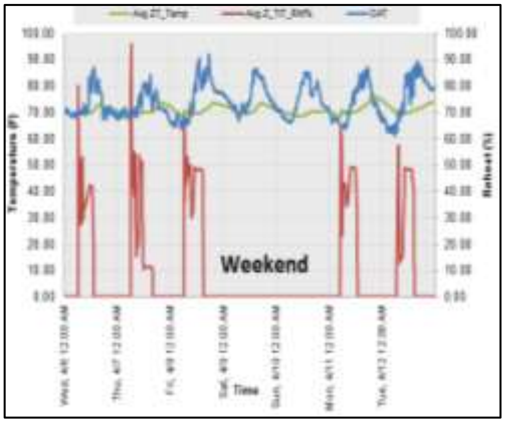
- Issue: There is significant reheat for exterior zone terminal unit in the summer
- Purpose: Determine whether the minimum air flow is too high

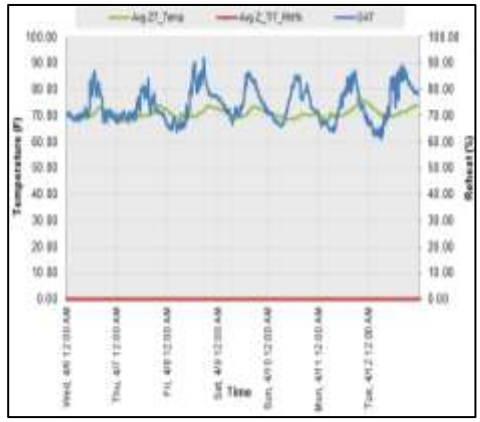
07 Pre-Re-Tuning Phase Zones, Slide 21

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.

Simultaneous Heating and Cooling for Exterior Zone Terminal Units: Example





07 Pre-Re-Tuning Phase Zones, Slide 22

- Notice that the outdoor air temperature in both graphs ranged from 70°F to 90°F. The space temperature is lower than outdoor air temperature during the day, indicating that cooling is on.
- In the graph on the left, heating valves are opening (up to 100%) when cooling is running. In the graph on the right, the reheat valves are closed, as they should be in summer.

RE-TUNING RECOMMENDATIONS FOR EXTERIOR ZONE

- REDUCE THE EXTERIOR ZONE TERMINAL UNIT MINIMUM AIR FLOW SETTING BASED ON VENTILATION REQUIREMENTS AND EXTERNAL WALL EXPOSURE

ENVELOP EXPOSURE	MINIMUM AIR FLOW (% OF MAXIMUM)
EAST, NORTH	15%
WEST	10%
SOUTH	10%
NORTHEAST CORNER OFFICE	20%

*WITH AT LEAST 75 CFM/PERSON FOR EACH ZONE

FROM 2004 ASHRAE STANDARD

07 PRE-RE-TUNING PHASE ZONES, SLIDE 23

- The table shows an example of minimum air flow that can be used for office terminal units.
- The north and east offices are set with a higher minimum because of reheat consideration.
- 75 cfm/person is calculated based on ASHRAE standard and assumed outdoor intake ratio.

Reheat Valve Leakage

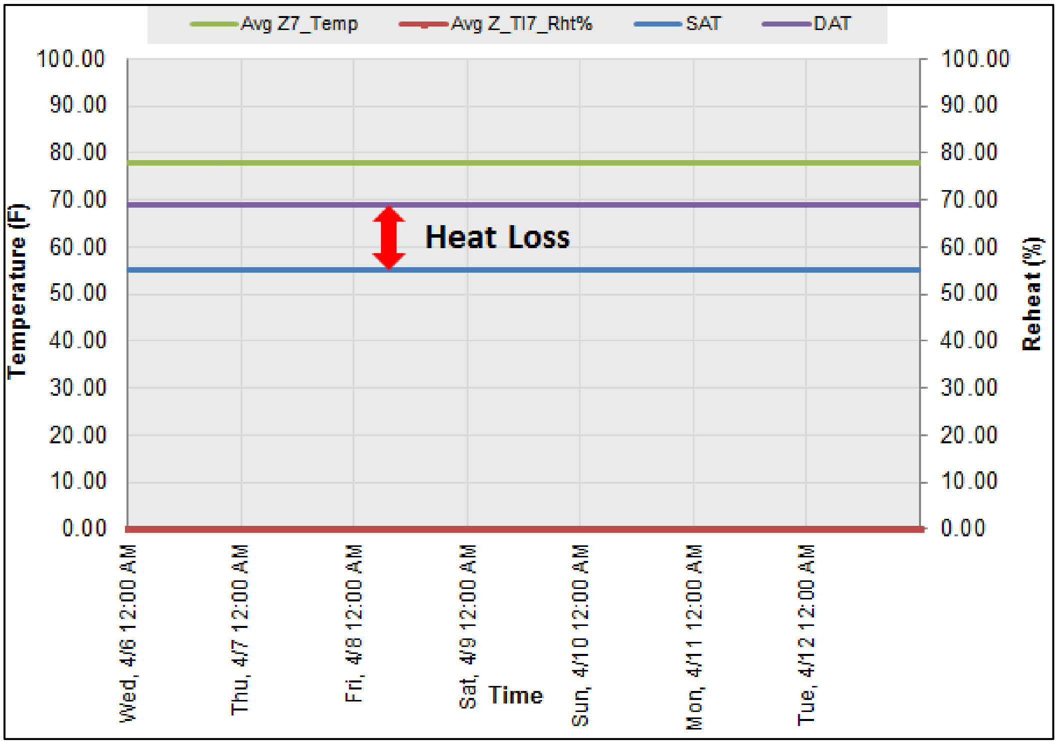
- Issue: Overheated space, cooling set point cannot be maintained
- Purpose: Determine if the reheating valve is leaking

07 Pre-Re-Tuning Phase Zones, Slide 24

Approach:

- Review plots of supply air temperature, discharge air temperature, and zone temperature vs. time.
- Look for temperature difference between AHU supply air temperature and reheat coil discharge air temperature (DAT). Any difference greater than 5 to 10°F should be further reviewed for leaking reheat valve or failed electric reheat control.
- If there is no trended data available for DAT, then a spot measurement at diffuser is recommended.

REHEAT VALVE LEAKAGE: EXAMPLE



07 PRE-RE-TUNING PHASE ZONES, SLIDE 25

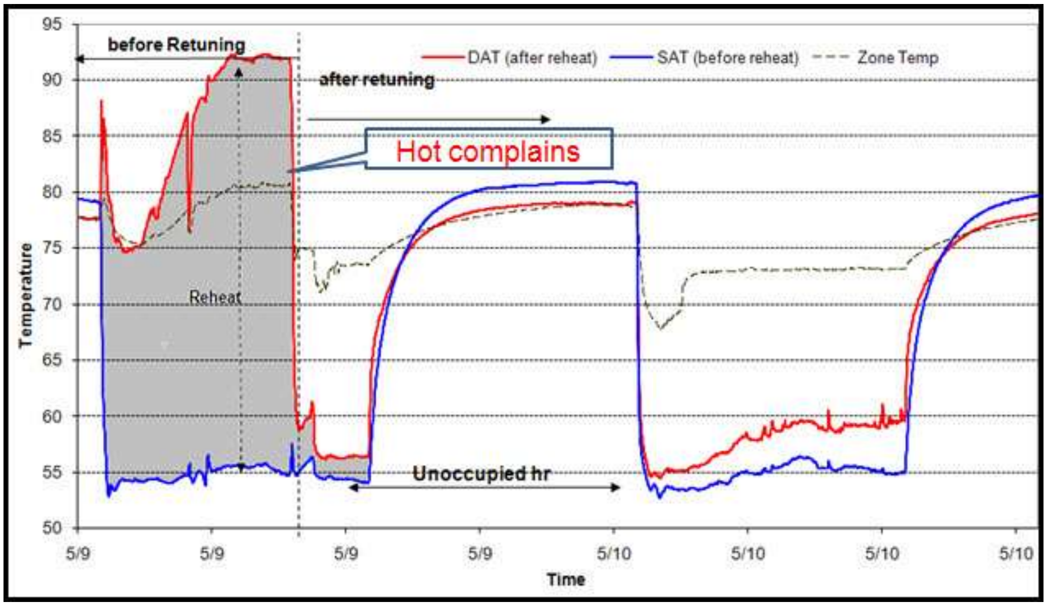
This trend graph reveals reheating valve leakage and no night setback.

How do you identify this situation if there's no discharge air temperature trending?

1. Hot complaints (or AHU cooling set point cannot be maintained).
2. Terminal unit is in cooling mode and damper is assumed to be open (not graphed).
3. Measure the discharge air temperature at the diffuser downstream of the terminal box and compare with the supply air temperature from the air handler.
4. The previous slide indicated a difference of more than 5 to 10°F was indicative of a possible reheat valve leak.

This trend graph also reveals no supply air temperature reset occurring at the main air handler (constant 55°F delivery).

FIXING REHEAT VALVE LEAKAGE



07 PRE-RE-TUNING PHASE ZONES, SLIDE 26

- The “before re-tuning” portion of the graph shows zone temperatures rising to above 80°F and discharge air temperatures above 90°F.
- Not surprisingly, there were numerous comfort complaints. After re-tuning, reheat ceased, as did the complaints.

Cold Complaints in Winter

07 Pre-Re-Tuning Phase Zones, Slide 27

- Cold complaints in winter fall into two categories: Control and O&M.
- Control reasons typically are either the terminal unit heating set point is too low or hot air is accumulating under the ceiling because of stratification.
- O&M reasons are usually hot water reheat valve malfunction or the electric reheat is tripped because of low air flow.

What do the graphics in this slide tell us? There’s a problem with zone control!

Cold Complaints in Summer

07 Pre-Re-Tuning Phase Zones, Slide 28

Cold complaints in summer fall into the same two categories. The primary control problem encountered is the minimum air flow setting is high and heating is not available—when this is the case, there should be complaints from many zones.

If cold complaints in summer are for a specific zone, they are usually caused by one of the following O&M issues:

- Damper or valve overriding is not released
- Damper control malfunction
- Thermostat is too close to a heat source or thermostat is in location that is not representative of zone (unoccupied office with door closed and lights and plug loads turned off)
- Other reasons include faults like worn-out valve and damper actuators, loss of calibration of temperature sensors, loss of calibration of air flow sensors, and thermostat or air flow sensor failure.

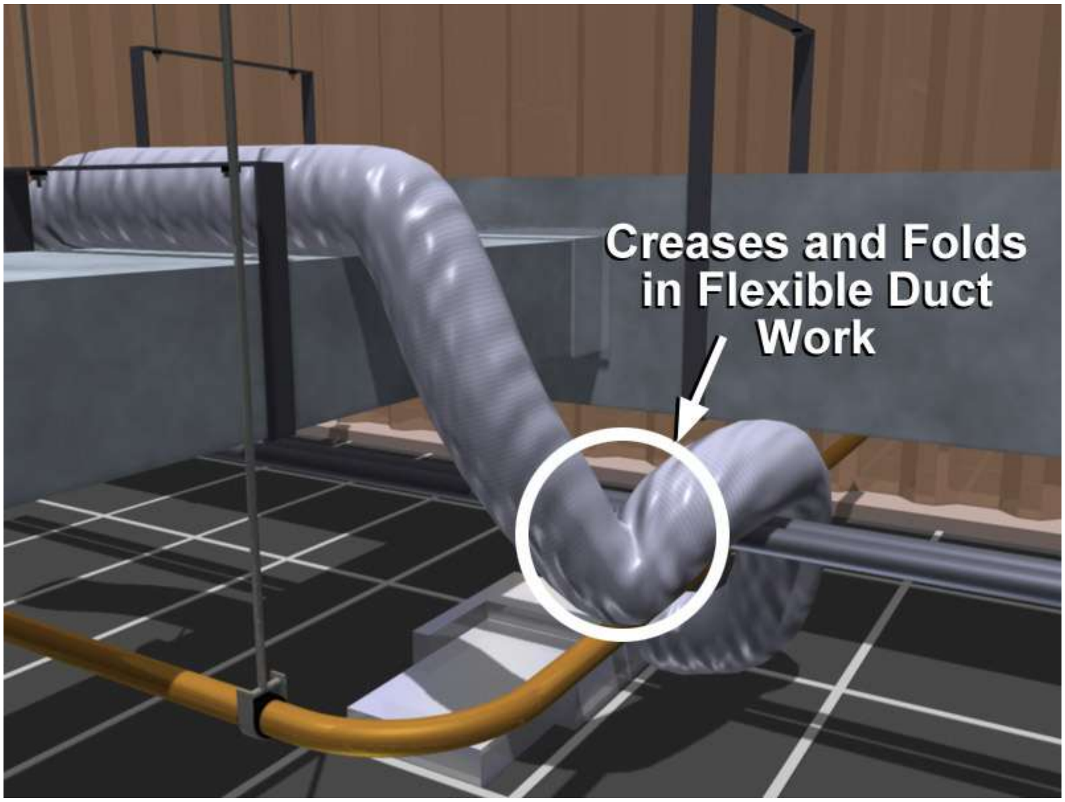
What do the graphics in this slide tell us? There’s a problem with zone control!

What's Wrong with This?

07 Pre-Re-Tuning Phase Zones, Slide 29

- Thermostat is located near heat source. Is that a problem?

HOT COMPLAINTS



07 PRE-RE-TUNING PHASE ZONES, SLIDE 30

- Creases and folds in flexible ductwork decrease flow and volume, and may increase fan energy consumption and increase potential for ductwork rupture.
- Look for and listen for ductwork rupture and/or ductwork disconnection. Duct delivery leakage into ceiling plenum spaces results in air not delivered to the occupied spaces below. This can lead to hot (or cold) complaints.

Other causes of hot complaints include:

- Reheat coil leakage
- Damper actuator malfunction (damper closed)
- Maximum air flow setting cannot meet the actual load condition (for example, exceed the design capacity)
- Duct design deficiency (undersized).

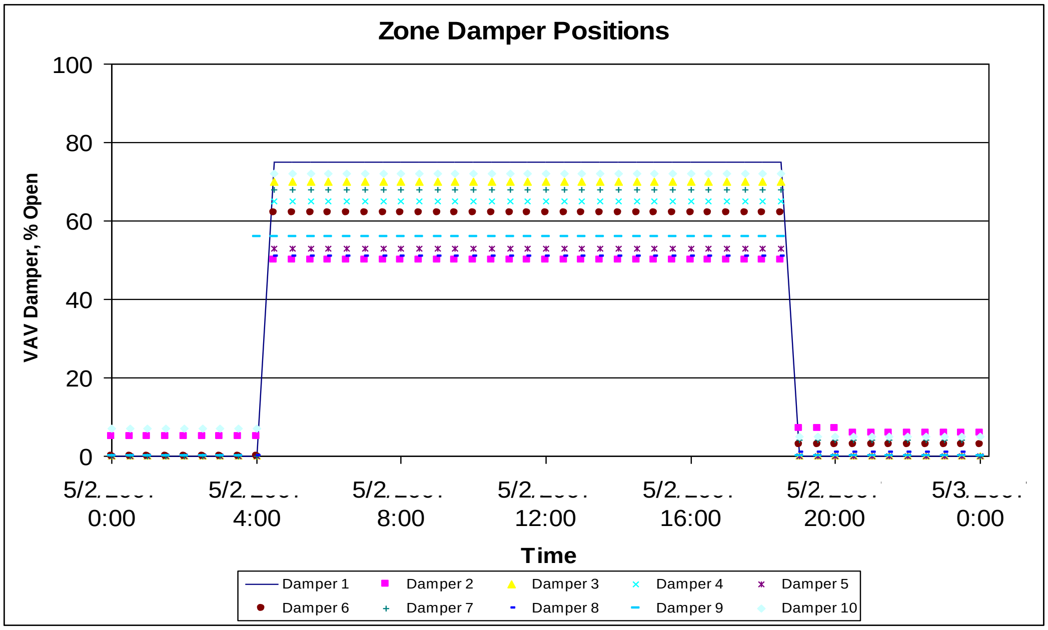
Zone Heating and Cooling Demands

- 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.
  - Note which areas of the building are in heating and cooling
  - Look for zones that are using both heating and cooling over relatively short periods of time

07 Pre-Re-Tuning Phase Zones, Slide 31

- Use a plot of number of zones in each mode and the outdoor temperature vs. time
- Building areas include interior core vs. perimeter zones or zones facing certain directions.
- Also look for zones that are cycling between heating and cooling.
- Potential issues to identify include:
  - Discharge 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.

ZONE HEATING AND COOLING DEMANDS: EXAMPLE GRAPHS

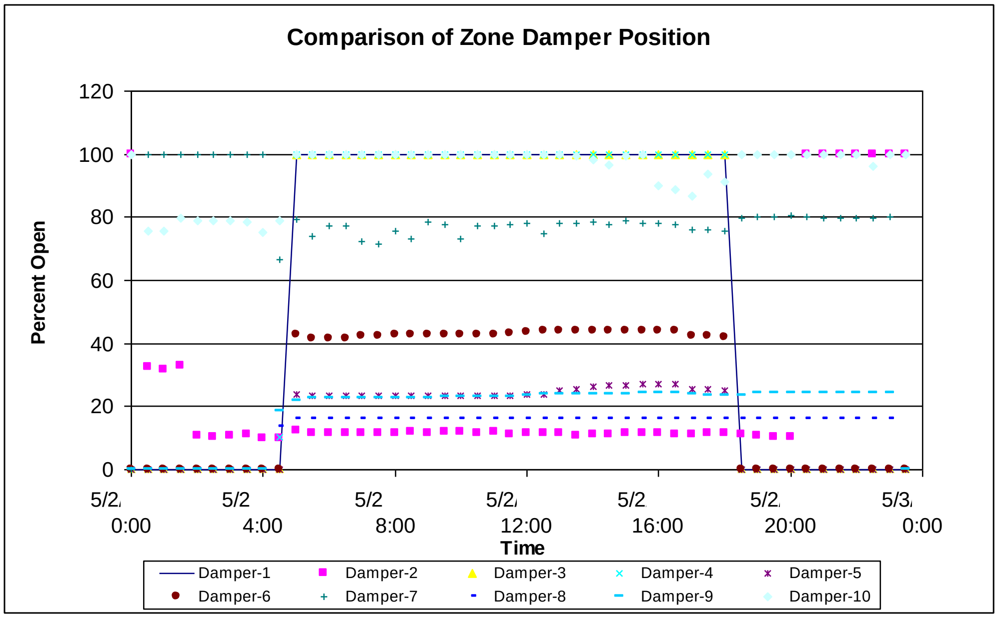


07 PRE-RE-TUNING PHASE ZONES, SLIDE 32

This graph shows a plot of VAV unit dampers vs. time for all VAV units served by an air handler.

- Shows very good distribution – most dampers are 50% to 75% open.
- The dampers fall to 0%, or very close to zero, and then at the scheduled time, they operate according to air flow set points.
- The dampers are not cycling open and close; instead, they hold a steady running position throughout the day when the building is occupied.

ZONE HEATING AND COOLING DEMANDS: EXAMPLE GRAPHS

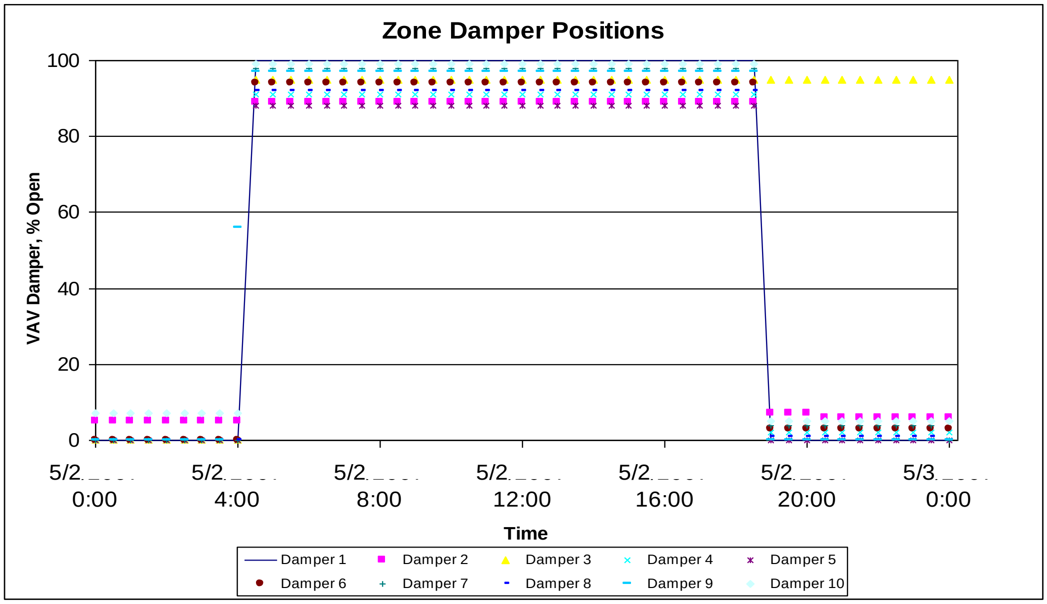


07 PRE-RE-TUNING PHASE ZONES, SLIDE 33

This graph shows a plot of VAV dampers vs. time for all VAV units served by an air handler.

- Damper position is all over the place—this is likely either a design problem or some dampers are broken.
- This situation is marginally OK and should be investigated.

Zone Heating and Cooling Demands: Example Graphs

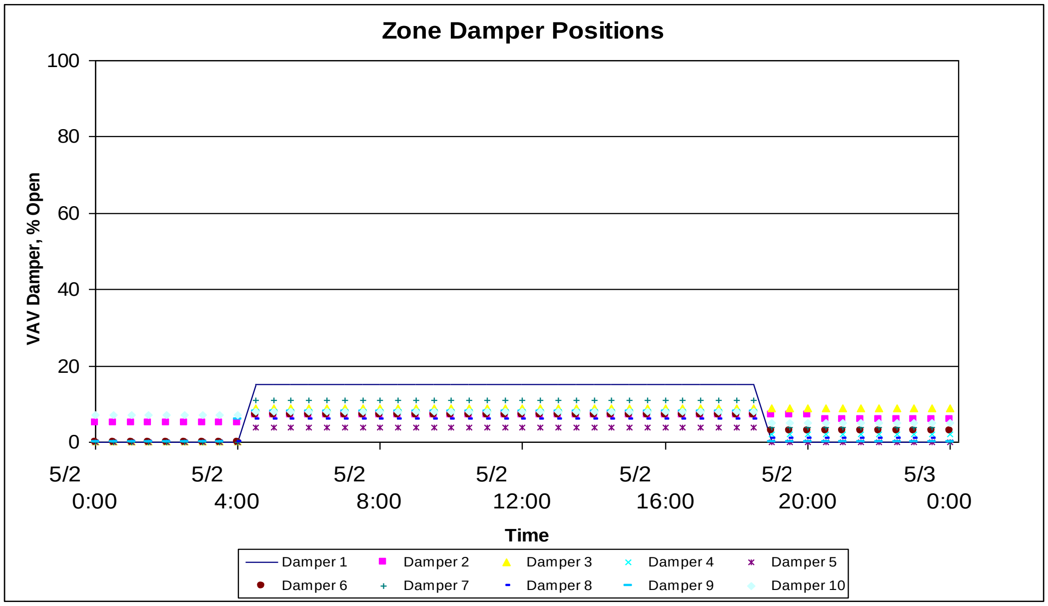


07 Pre-Re-Tuning Phase Zones, Slide 34

This graph shows most of the dampers fully open. Remember, they should be 50% to 75% open. Some re-tuning is definitely called for here.

- Verify that air handler supply static pressure is not too low, and is adequate for the VAV box design (VFD or inlet vanes are working properly, etc.).
- Verify that air handler temperature control is working properly (air handler supply temperature is meeting set point and set point, is not too high, adequate for zone cooling loads).
- Verify that reheat system is not running (summer shutdown) or if running, is not excessively hot/warm and that the pumping system is not running at excessively high pressures that would cause terminal box reheat control valves to be forced off of their seats (self-induced coil leakage).
- Verify that terminal box controllers are powered up and communicating properly with BAS.

ZONE HEATING AND COOLING DEMANDS: EXAMPLE GRAPHS



07 PRE-RE-TUNING PHASE ZONES, SLIDE 35

This graph is nearly the opposite of the previous graph. In this instance, all the dampers are closed or nearly closed. Again, they should be 50% to 75% open.

- Verify that air handler supply static pressure is not too high, and is adequate for the VAV box design (VFD or inlet vanes are working properly, etc.).
- Verify that air handler temperature control is working properly (air handler supply temperature is meeting set point and set point, is not too low, adequate for zone heating loads – especially if the reheat system is shut off for the summer).
- Verify that reheat system is running (if not during the summer shutdown) and if running, is not excessively cool and that the pumping system is not running at excessively low pressures that would cause terminal box reheat valves to not meet design flow requirements when reheat is needed.
- Verify that terminal box controllers are powered up and communicating properly with BAS.

RE-TUNING TERMINAL UNITS: EXAMPLE

- 900,000 SF OFFICE BUILDING
- MAJOR ISSUE: COLD COMPLAINTS IN SUMMER
- MAJOR FINDINGS:
  - 712 VAV BOXES SERVING THE INTERIOR ZONES AND 624 FAN-POWERED UNITS SERVING THE EXTERIOR ZONES
  - INITIAL DESIGN MINIMUM COOLING AIR FLOW RATE RANGED FROM 30% TO 50% OF THE MAXIMUM COOLING AIR FLOW RATE FOR TERMINAL BOX
  - THE TRENDED DATA SHOWED SIGNIFICANT SIMULTANEOUS HEATING AND COOLING

07 PRE-RE-TUNING PHASE ZONES, SLIDE 36

- Before re-tuning, building had Energy Star rating of 70.
- Besides the cold complaints, there was a noise issue on return fan.
- Had to run the absorber chiller in the summer to reduce peak demand.

O&M CHECKLIST FOR TERMINAL UNITS

- FIX OR REPLACE LEAKING VALVES
- FIX DAMPER ACTUATOR
- VERIFY IF PNEUMATIC TUBE IS PLUGGED INTO THE ACTUATOR
- FOR ELECTRIC ACTUATORS, VERIFY THAT WIRES/TERMINAL PLUGS ARE PROPERLY CONNECTED/TERMINATED AND NO LOOSE WIRES OR CABLING
- VERIFY FLOW SENSOR ACCURACY

07 PRE-RE-TUNING PHASE ZONES, SLIDE 37

This slide shows the operations & maintenance checklist for the troubled terminal unit.

- When checking the damper, make sure the damper linkage is connected.
- For flow sensors, if the inlet conditions are poor and not compensated in the flow sensor calibration, perform calibration.
- For flow sensors, verify that that sensing lines (poly tubing) are connected to the correct sensing ports (high side and low side). Generally, high side port is upstream and low side port is downstream, but they should be labeled or indicated as "H" for high and "L" for low.
- Besides flexible duct kinks and obstructions that can affect air flow from the terminal box, ensure that the balancing damper (often installed/provided upstream of the terminal box) is open or at its pre-set opening, as per the air balance (TAB) contractor.
- Verify that electric reheat disconnects are turned on and that high temperature or low air flow safety limits are reset.
- Verify that hot water control valves and coils having isolation valves, and have their isolation valves opened.
- Verify that water balancing valves are open or at their pre-set opening, as per the water balance (TAB) contractor.

General Benefits of Re-Tuning Zone Terminal Units

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

07 Pre-Re-Tuning Phase Zones, Slide 38

- Save money and energy!

FAN-POWERED BOX TERMINAL UNITS
▶ FAN-POWERED VAV TERMINALS ARE A POPULAR CHOICE FOR HEATING AND COOLING PERIMETER ZONES ○ USE “FREE” HEAT ○ REASONABLE INITIAL COST

07 PRE-RE-TUNING PHASE ZONES, SLIDE 39

Why FPB?

- Fan-powered VAV terminals are a popular choice for heating and cooling perimeter zones.
- In addition to the inherent VAV economy, fan-powered terminals make use of the “free” heat that collects in the ceiling plenum after being emitted by lighting, people, and equipment.
- Reasonable initial cost, capacity for improved air motion, and low operating costs are additional reasons for the popularity of fan powered VAV terminals.
- The fan-powered box is designed for better ventilation in the winter. The fan can be operated during the heating season to provide a better mix and air distribution.

Collecting Basic Information

Table 1: Fan-Powered Box Type

Type of FPB	Quantity	Notes
Parallel		
Series		

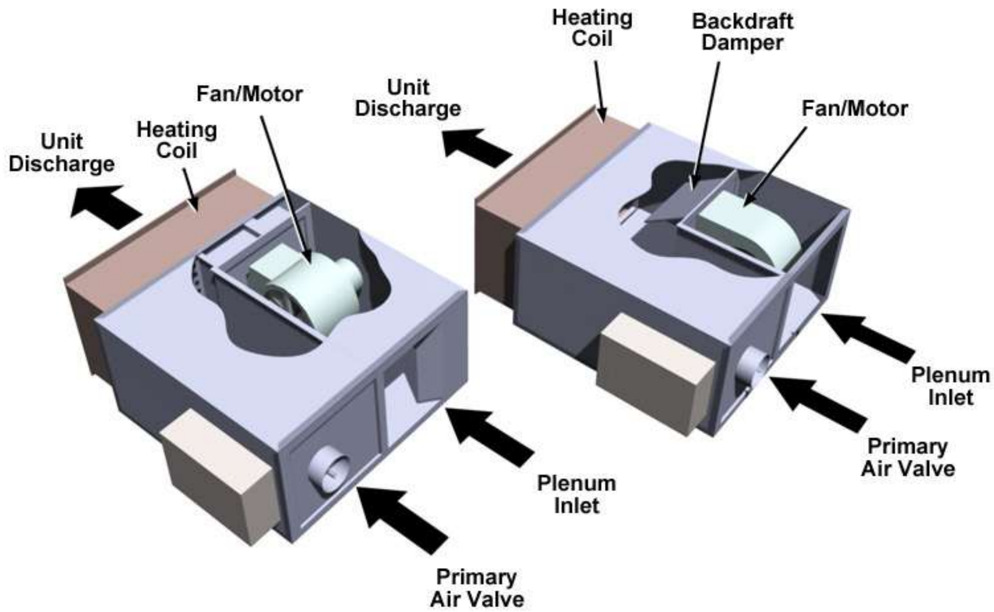
Table 2: Fan-Powered Box Operation

Questions	Answer
Electrical reheat or hot water reheat?	
Are FPBs operated 24/7	
Any stage control (high-low speed) for the fan?	

07 Pre-Re-Tuning Phase Zones, Slide 40

- When collecting basic information, it's a good idea to develop a matrix, as shown in the examples in this slide.
- General information to collect include type of fan-powered box (FPB) (series or parallel link), number of each terminal unit, and heating source.
- Specific information includes the fan-powered boxes run 24/7; are there any cold or hot spots for a specific area; do the fan-powered boxes serve the exterior zone only?
- Are the series fan-powered boxes interlocked to run with the primary AHU and shut off with the primary AHU?
- Are the series fan-powered boxes capable of standalone night setback operations during cold weather (the FPB can run without the primary fan to heat the perimeter space)?

Series and Parallel Fan-Powered Boxes



07 Pre-Re-Tuning Phase Zones, Slide 41

- Series type is shown on the left. Parallel fan-powered box is shown on the right.
- A series type FPB provides a constant volume of air that is a mixture of primary air and induced return plenum air. The fan runs continuously in series with the primary air. The thermostat calls for more primary air on a demand for cooling, or less primary air as cooling demand decreases. The decrease on primary air via the box damper results in less load on the primary supply fan.
- A parallel type FPB is variable volume. Fan runs in parallel with primary air and runs only when needed (for heating in the space).
- Series flow terminal fans run during all occupied and some unoccupied periods, with operating times ranging from 3000 to 4000 hours annually.
- Parallel flow terminal fans run during periods of heating and low-load cooling with operating times ranging from 500 to 2000 hours annually, depending on the climate and other factors.

ADVANTAGE OF SERIES VS. PARALLEL

WHILE BOTH TYPES OF FAN-POWERED TERMINALS PROVIDE VAV ENERGY SAVINGS AT THE CENTRAL FAN, THEY DIFFER FROM EACH OTHER IN THEIR INLET STATIC PRESSURE REQUIREMENTS

- PARALLEL FLOW TERMINALS, LIKE NON-FAN TERMINALS, REQUIRE A MINIMUM INLET STATIC PRESSURE TO FORCE THE AIR THROUGH THE PRIMARY AIR DAMPER, CASING, DOWNSTREAM DUCT WORK, AND DIFFUSERS
- IN SERIES FLOW TERMINALS, THE FAN BOOSTS THE AIR THROUGH THE DISCHARGE DUCT AND DIFFUSERS, SO THE INLET STATIC PRESSURE MUST ONLY OVERCOME LOSSES THROUGH THE PRIMARY AIR DAMPER

07 PRE-RE-TUNING PHASE ZONES, SLIDE 42

- Typically for parallel flow terminals, the resistance is 0.2 in. WG (water gauge) for the damper and 0.3 in. WG for ductwork and diffusers, or a total of 0.5 in. WG
- In series flow terminals, the central fan and duct system can be designed for less inlet static pressure, typically 0.1 in. to 0.2 in. WG.

Fan-Powered Box Trend Data Collection and Analysis

- Select zones for trending
- Refer to the zone/VAV unit monitoring plan
- Select parameters to trend

07 Pre-Re-Tuning Phase Zones, Slide 43

- The best approach is to trend all zones' operations if possible.
- If there are bandwidth constraints of data trending, you may select
  - Zones that are exposed to different orientations and zones that serves different needs
  - Zones with thermal comfort issues
  - Zones with operation and maintenance issues.
- Trend as many of the following parameters as possible:
  - Supply air temperature from air handler
  - Discharge air temperature from the fan-powered box
  - Zone air temperature and set point
  - Terminal fan motor in fan-powered box On/Off status
  - Damper position
  - Zone occupancy mode.

  Note: The supply air temperature trend is not a repeating trend. We may just use the trend from the air handler.

FAN-POWERED BOX TREND DATA ANALYSIS

- USE ECAM TO ANALYZE THE DATA COLLECTED
- KEY CONDITIONS TO LOOK FOR IN THE CHARTS:
  - FAN-POWERED BOX FAN IS ON AT UNOCCUPIED HOUR
  - SIGNIFICANT MIXING OF RETURN AND PRIMARY AIR DURING SUMMER/COOLING SEASON
  - SIMULTANEOUS HEATING AND COOLING

07 PRE-RE-TUNING PHASE ZONES, SLIDE 44

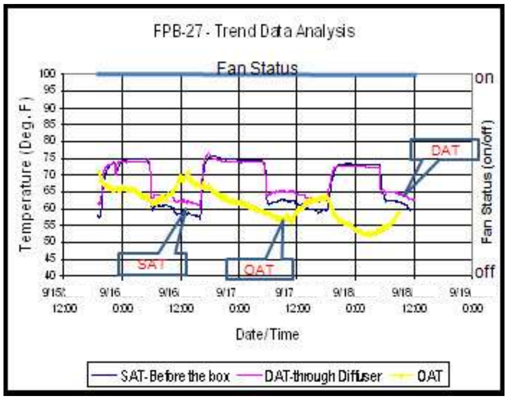
A likely reason for 24/7 FPB fan operation is that unoccupied hour setback is not defined or enabled.

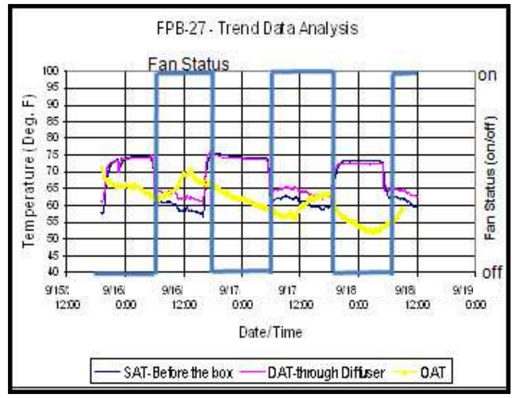
- Determine whether the FPB fans follow the same schedule as the AHU provides the primary air.
- Determine if the FPB fans are operating during unoccupied hours.
- Determine if the FPB fans are interlocked (hardwired or control logic in DDC/BAS) with AHU.

Approach:

- Review plots of FPB fan status vs. time.
- Look for the fan status at unoccupied hours and determine the FPB operation schedule.

FAN-POWERED BOX EXAMPLE GRAPHS



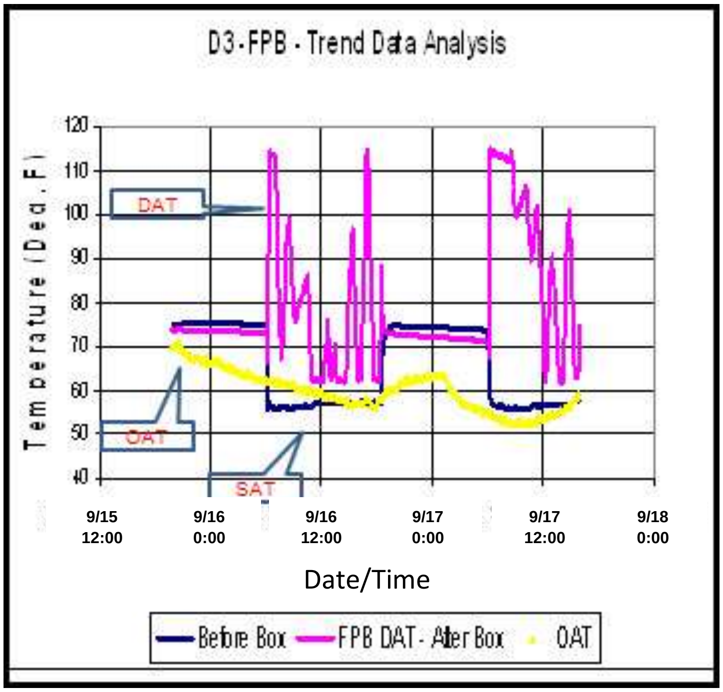


07 PRE-RE-TUNING PHASE ZONES, SLIDE 45

- In the graph on the left, the fan-powered box fan is operated 24/7, although the air handler is off at night (as indicated by the supply-air temperature plot).
- The graph on the right shows night setback is in place for the FPB.
- The terminal fan can be interlocked with AHU. Series terminal fans should be interlocked to be energized ahead of the central fan to prevent back flow of primary air into the ceiling plenum and to prevent backward rotation of the terminal fan.

ISSUE: SIGNIFICANT REHEAT FOR INTERIOR ZONE

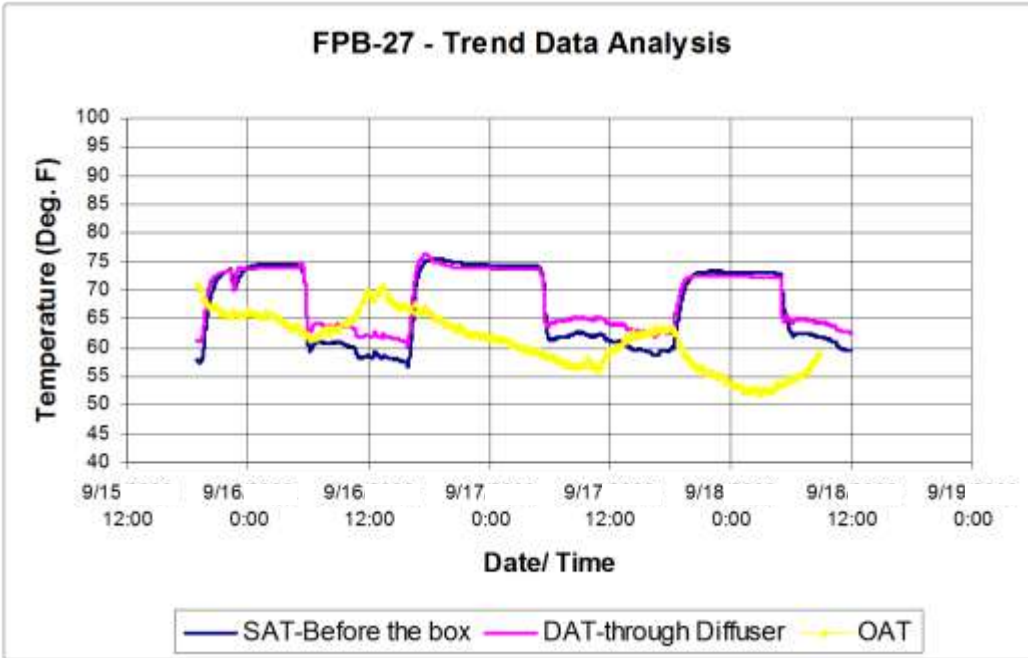
- TO DETERMINE IF THE MINIMUM AIR FLOW SETTING (PRIMARY AIR) IS TOO HIGH, REVIEW PLOTS OF SUPPLY AIR TEMPERATURE AND DISCHARGE AIR TEMPERATURE AFTER MIXING/REHEAT VS. TIME.
- LOOK FOR THE TEMPERATURE DIFFERENCE BETWEEN AND AFTER MIXING.



07 PRE-RE-TUNING PHASE ZONES, SLIDE 46

- This graph shows two series linked terminal fans for an interior zone office (executive office). It was unoccupied at night, during the trending.
- In the graph, the supply air temperature (primary air from the air handler) ranges from 55°F to 57°F, and the discharge air temperature after the fan-powered box reheat ranges from 62°F to 115°F. There is significant reheat (left side) at the fan-powered box.

INTERIOR ZONE: EXAMPLE GRAPH



07 PRE-RE-TUNING PHASE ZONES, SLIDE 47

- This graph shows good operation in the interior zone. Discharge air temperature and supply air temperature are together maintaining a reasonable temperature, and there is no significant reheat.

Fan-Powered Box Re-Tuning Recommendations

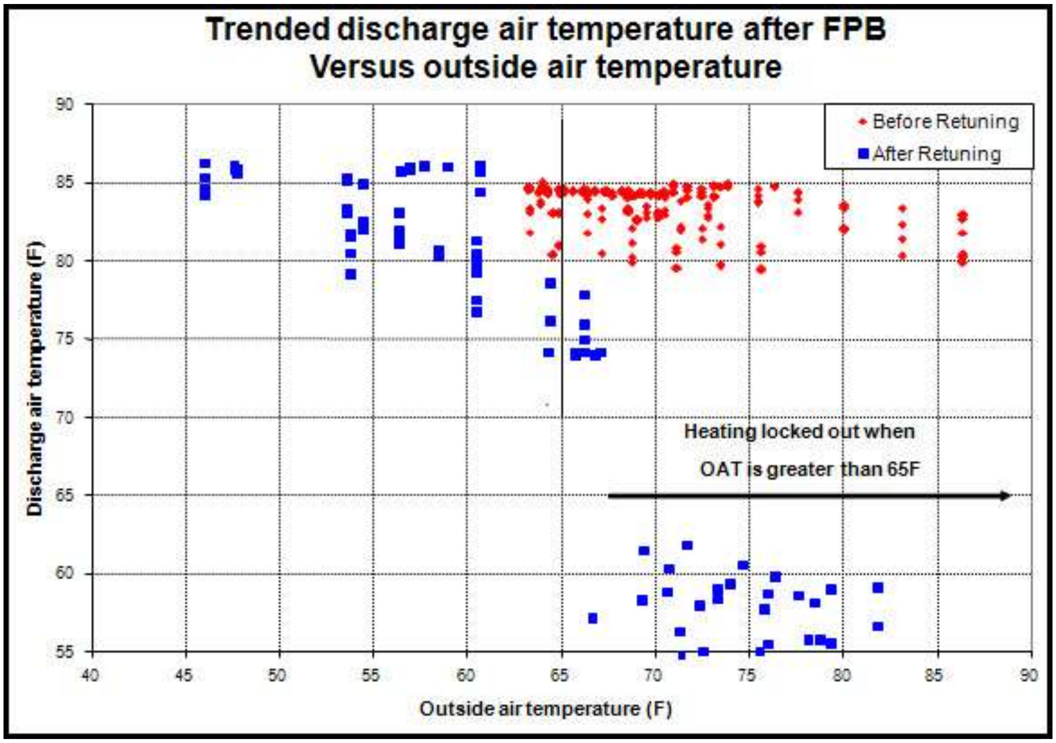
- Define and enable unoccupied setback control if possible
- Interlock the terminal fan with the air handler control
- Reduce the box primary minimum air flow setting based on ventilation requirements

07 Pre-Re-Tuning Phase Zones, Slide 48

- When reducing the primary minimum air flow setting, remember you need at least 75 cfm per person.

- For constant-speed terminal fan, shut it off during summer/cooling season to save the fan power when there is no need for heating or recirculation. Also close heating coil valve during summer/cooling season to minimize simultaneous heating and cooling, or shut down the boiler and pumps, if they only serve zone reheat loads. These recommendations are for parallel fan-powered boxes, not series fan-powered boxes (you don't want to burn up the motor in series FPB)!

RE-TUNING FAN-POWERED BOXES: EXAMPLE



07 PRE-RE-TUNING PHASE ZONES, SLIDE 49

- Office building in North Florida
  - 130 FPBs with reheat (parallel type) with electric reheat serving exterior zones
  - Open spaces are served by both electric reheat FPB and cooling-only VAV terminal boxes.
- Re-tuning strategy
  - Minimum cooling air flow set to zero
  - Minimum and maximum heating air flow is set to zero for FPBs serving open space (used as a call center) and hallways.
- Electric heating is disabled when outdoor air temperature is greater than 65°F for FPB serving the open space or hallway to prevent the simultaneous cooling and heating. Before re-tuning, the primary air was mixed with plenum air (72°F) and reheat to between 80 and 85°F. It fought with cooling-only VAV terminal box during the summer.

RE-TUNING FAN-POWERED BOXES: EXAMPLE

- OFFICE BUILDING WITH 710, 500 SQ FT CONDITIONED AREA
- RE-TUNE BUILDING
- REALIZE ENERGY AND COST SAVINGS:
  - BIN DATA >65°F: 7311 HOURS
  - SAVINGS 1,757,493 KWH/YR ($154,617/YR)

07 PRE-RE-TUNING PHASE ZONES, SLIDE 50

Office building had

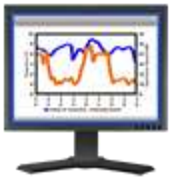
- 816 series FPBs serving exterior and interior zones
- two-stage electric heaters installed on the exterior zone terminal boxes with 3 kW to 4 kW capacity
- nominal power for the series ranged from 1/6 hp to 1 hp (majority were ¾ hp).

Re-tuning measures:

- Removed series fan for interior zone boxes.
- Sealed plenum air opening for interior zone boxes.
- Switched exterior zone FPB fans to low speed in summer and switch back to normal speed during winter/heating season.

Benefits from FPB Re-tuning:

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



Chapter 8: Central Utility Plant: Pre-Re-Tuning and Re-Tuning

INSTRUCTOR GUIDANCE

TIME: 30 MINUTES

MATERIALS: POWERPOINT SLIDES 09 PRE-RE-TUNING OF CENTRAL UTILITY PLANT

LESSON GOAL: UNDERSTAND THE PRE-RE-TUNING AND RE-TUNING PROCESS FOR THE CENTRAL PLANT

LEARNING OBJECTIVES:

- UNDERSTAND THE POINTS TO PLOT FOR THE CENTRAL PLANT
- GENERATE CENTRAL PLANT TREND GRAPHS
- ANALYZE CENTRAL PLANT TREND GRAPHS
- RE-TUNE THE CENTRAL PLANT

CHILLED WATER LOOP (CHILLER AND CHILLED WATER PUMP)

- COLLECT BASIC INFORMATION

GENERAL

- CHILLER CAPACITY (TONNAGE), TYPE, AND NUMBER
- SYSTEM CONFIGURATION (PRIMARY ONLY OR PRIMARY-SECONDARY LOOP)
- VFD ON ANY PUMPS?

SPECIFIC

- CHILLER ENABLING CONDITIONS
- CHILLED WATER TEMPERATURE SET POINT
- DIFFERENTIAL PRESSURE SET POINT FOR SECONDARY CHILLED WATER PUMP CONTROL

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 1

- Collect basic information about the chiller and chilled water pump.
- Under "Specific", enabling conditions include outdoor air temperature.
- Under "Specific", other enabling conditions are possible (such as time of day, internal load or control valve positions, etc.).
- Under "Specific", chilled water temperature set point, if reset, should be noted along with the reset high/low values and reset parameters.
- Under "Specific", need to also add chilled water supply temperature (CHWST) and chilled water return temperature (CHWRT) temperatures, maximum chilled water coil control valve command, and VFD Pump speed, because these are further discussed in the following slides.

CHILLED WATER SUPPLY TEMPERATURE

- Chilled water supply temperature (CHWST) is generally set at a constant value
- Several problems can arise with CHWST

08 Pre-Re-Tuning of Central Utility Plant, Slide 2

- Constant CHWST can lead to loss in chiller efficiency, especially when all cooling coil valves are partially open and the chilled water pump is at low speed.
- Problems arise when
  - Maximum cooling coil valve is less than 50% open
  - Chilled water pump VFD is at low speed (<50%) and
  - Loop delta T is less than 8°F.

Chiller Data Analysis: CHWST Reset

▶ Purpose:

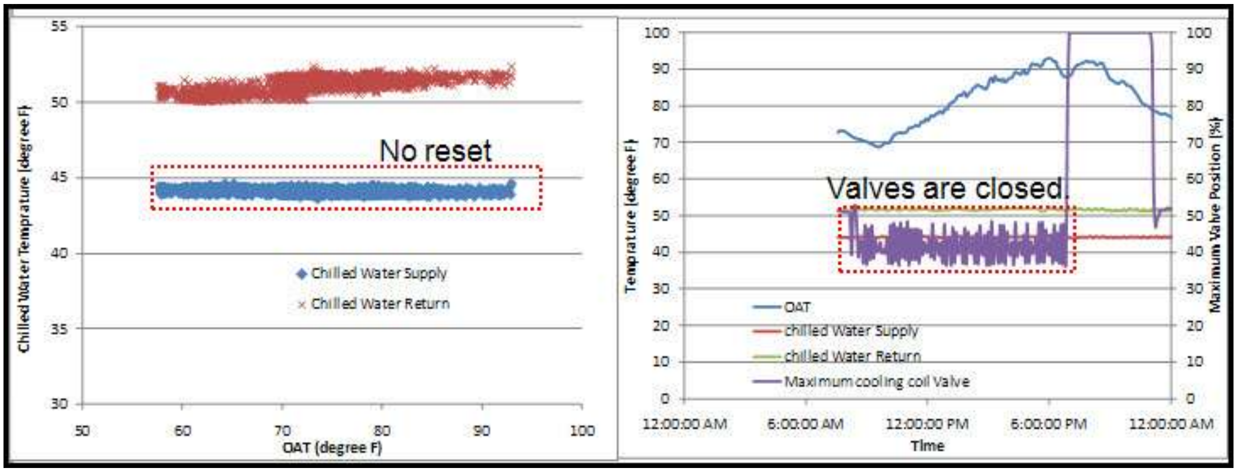
- Determine if the CHWST is too low
- Determine potential of resetting CHWST to a higher value at partial load condition

08 Pre-Re-Tuning of Central Utility Plant, Slide 3

Approach:

- Review plots of CHWST, CHWRT, and maximum cooling coil valve vs. time.
- Review plots of CHWST and CHWRT vs. OAT (outdoor air temperature).
- Check if the CHWST is constant, is the loop delta T low (< 8°F)?
- Check if maximum cooling coil valve position is less than 90%?

CHILLER EXAMPLE GRAPH



08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 4

- The chiller water supply temperature is 44°F, and the chiller water return temperature is about 51°F.
- The maximum valve position is less than 50°F during the day (6am to 6pm).
- The secondary chilled water pump is operated at minimum speed. Therefore, CHWST can be reset to higher value to improve the chiller efficiency.

RE-TUNING: RESET CHWST

- MAKE SURE CHILLER PLANT IS NOT OPERATED AT FULL LOAD CONDITION
- MAKE SURE COOLING COIL VALVES ARE NOT FULLY OPEN
- MAKE SURE THERE IS NO CRITICAL WATER LOOP, FOR EXAMPLE DATA CENTER AIR HANDLER

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 5

- Low chilled water flow—for example 60%--is indicative of a low-load condition.
- If the cooling valves are not fully open, a variable speed chilled water pump should not operate at high speed.

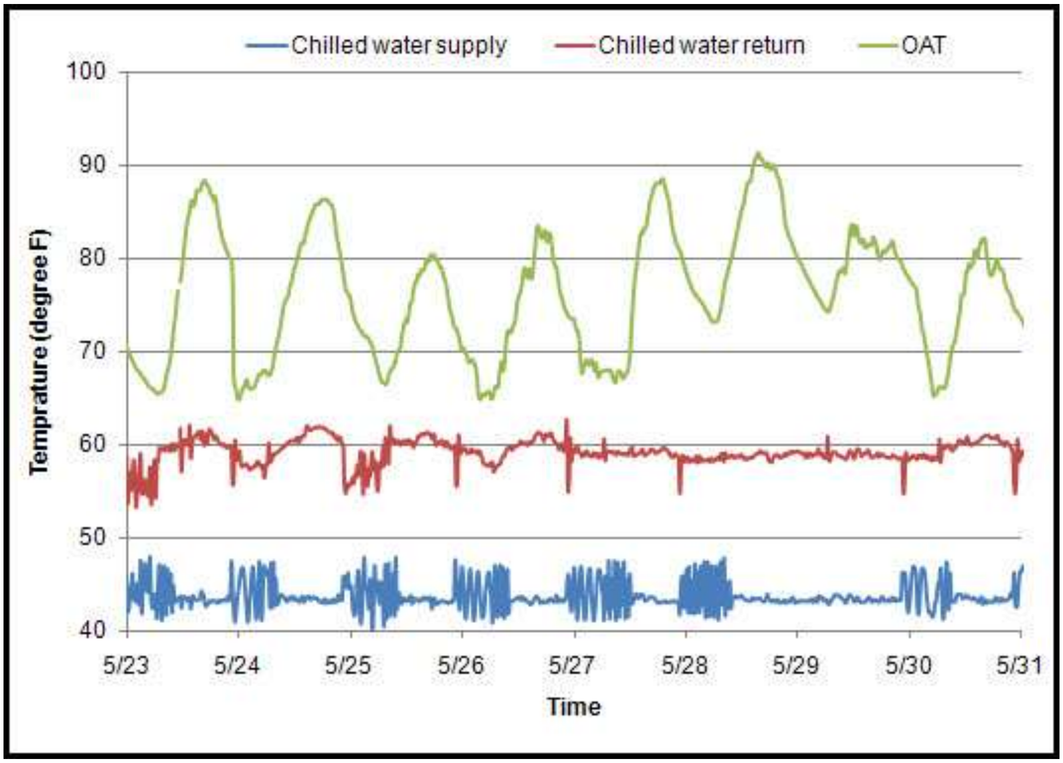
RE-TUNING: RESET CHWST (CONTINUE)

- INCREASE CHWST SET POINT 0.5°F AT A TIME, UP TO 5°F HIGHER THAN THE DESIGN VALUE
- IF MAXIMUM OPEN VALVE IN THE PRIMARY CHILLED WATER LOOP IS LESS THAN 90 TO 95% OPEN, INCREASE THE CHILLED WATER SUPPLY TEMPERATURE
- IF MORE THAN ONE VALVE IS 100% OPEN, DECREASE THE CHILLED WATER TEMPERATURE GRADUALLY

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 6

- To prevent the chiller from tripping off, don't increase the CHWST set point too fast (change set point at frequency of no greater than 10 to 15 minutes).
- Ensure system energy efficiency is not affected.
- Increasing chilled water temperature may increase distribution pump (secondary pump) power consumption.
- Use differential pressure reset control to optimize secondary chilled water pump control.
- If chilled water pump speed increases to more than 80%, CHWST set point should be lowered gradually to design set point.

RE-TUNING: CHWST RESET (CONTINUED



08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 7

- The maximum valve is less than 90%.
- Reset CHWST from 42°F to 48°F, with average loop delta T maintained at 14°F. The chiller efficiency is improved.

DIFFERENTIAL PRESSURE FOR CHILLED WATER PUMP

- IT IS COMMON PRACTICE TO INSTALL DIFFERENTIAL PRESSURE (DP) SENSOR
- AT PARTIAL LOAD, COOLING COIL VALVES ARE FORCED TO CLOSE TO MAINTAIN DESIGN DP SET POINT AND CHILLED WATER PUMPS ARE OPERATED AT HIGH SPEED

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 8

- DP set point is generally set to meet the design condition.
- Issues arise when maximum cooling coil valve is less than 50% open and/or when chilled water pump VFD is operated at high speed (>75%).

Chiller Data Analysis: DP Reset

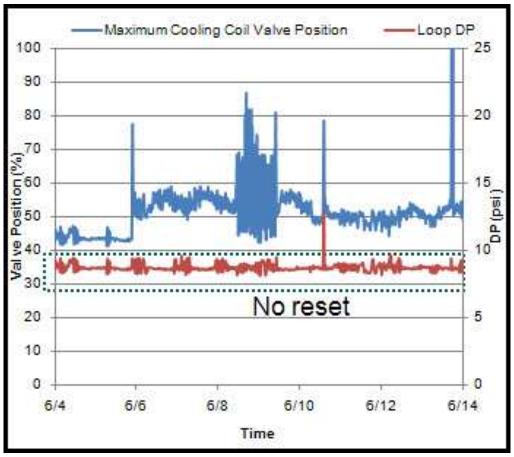
- Purpose:
  - Determine if the loop DP set point is constant
  - Determine the potential of resetting the DP to a lower value at partial load condition

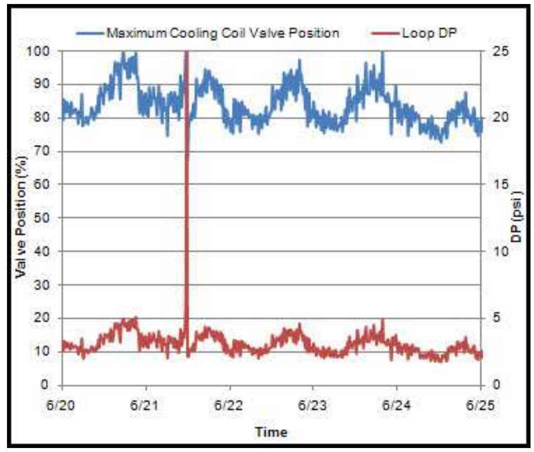
08 Pre-Re-Tuning of Central Utility Plant, Slide 9

Approach:

- Review plots of loop DP, maximum cooling coil valve position vs. time.
- Review plots of CHWST and CHWRT vs. OAT.
- Check whether DP is constant.
- Check whether maximum cooling coil valve position is less than 95%.

CHILLER DP EXAMPLE GRAPH





08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 10

- In the graph on the left, the DP set point is at 8 psi (end of loop), and the maximum valve position is between 40% and 60% most of the time.
- In the graph on the right, the reset DP is between 2.5 and 5 psi, and the valves open more.

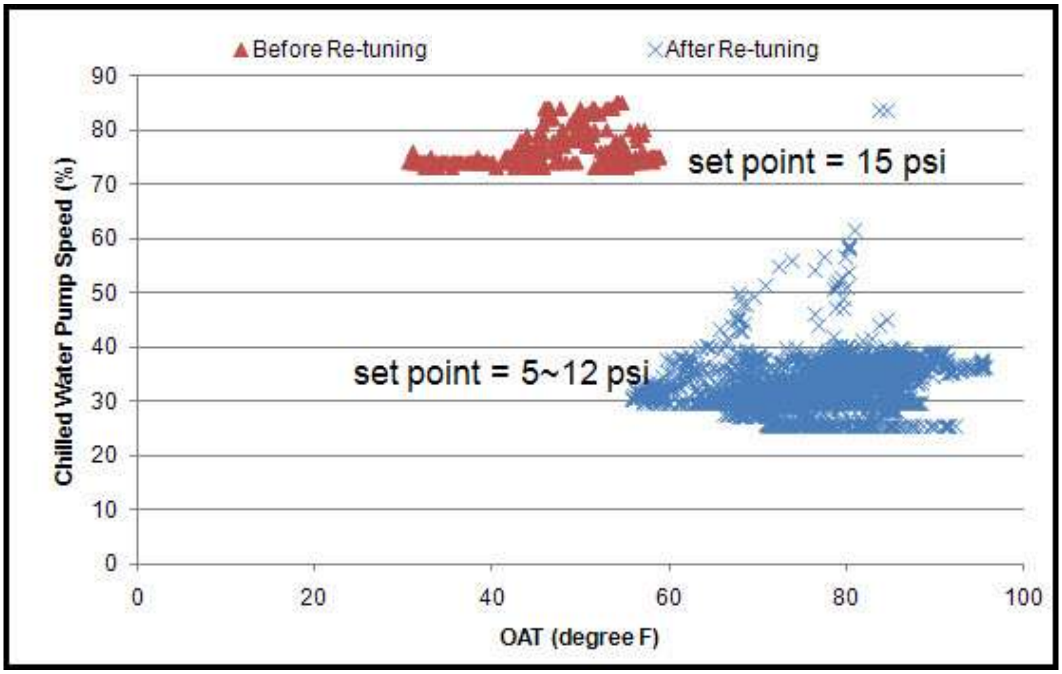
Re-Tuning: Resetting Differential Pressure

- Reduce loop DP set point gradually at partial load condition
- Determine the minimum loop DP based on system configuration and coil condition
- Increase the loop DP set point to design value if the maximum cooling coil value opens to 100%

08 Pre-Re-Tuning of Central Utility Plant, Slide 11

- If the maximum open valve in the chilled water loop is less than 95% open, decrease the DP set point 0.5 psi at 15-minute intervals.
- For example, if DP sensor is installed across the remote cooling coil in the loop; lower loop DP to 5 psi.
- Can implement in building automation system—a dead band is recommended in the control.

RESETTING DIFFERENTIAL PRESSURE: EXAMPLE GRAPH



08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 12

- This graph shows the difference between the secondary pump speed before and after DP set point re-tuning. Before re-tuning, the pump speed was 15 psi (oversized pump).
- Why was chilled water plant even running in February?

RE-TUNING: CHILLER STAGING CONTROL

- RUNNING CHILLERS IN HIGH-EFFICIENCY RANGE CAN RESULT IN SIGNIFICANT ELECTRICAL ENERGY SAVINGS AND CAN IMPROVE THE RELIABILITY OF PLANT OPERATION
- DETERMINE AND UNDERSTAND THE OPTIMAL LOAD RANGE FOR EACH CHILLER
- TURN ON THE MOST EFFICIENT CHILLER FIRST
- TURN ON ADDITIONAL CHILLERS TO MAINTAIN LOAD RATIO (CHILLER LOAD OVER THE DESIGN LOAD) WITHIN THE OPTIMAL EFFICIENCY RANGE FOR EACH CHILLER

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 13

- Optimal load range information should be available from the chiller manufacturer. For example, kW/ton has the minimum value for some old chillers when the load varies from 50% to 80% of the design value.
- When turning on the most efficient chiller first, optimize the pump and cooling tower fan operation accordingly.

CONDENSING WATER LOOP

▶ COLLECT BASIC INFORMATION

GENERAL

- CAPACITY (TONNAGE) AND NUMBER
- VFD ON THE PUMPS?
- VFD ON TOWER FANS?
- ANY WATER-SIDE ECONOMIZERS?

SPECIFIC

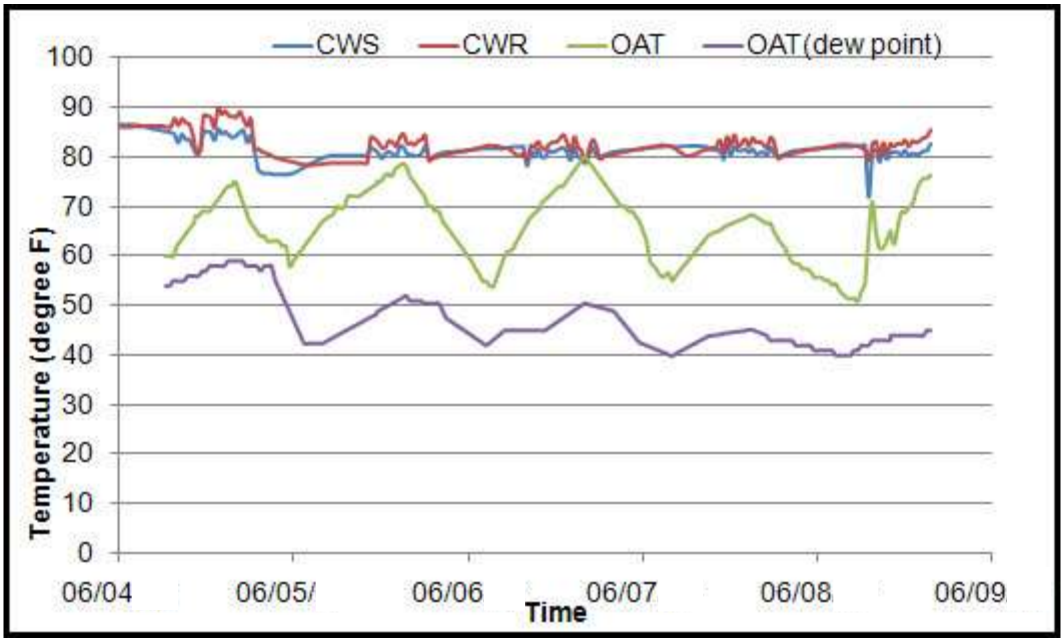
- CONDENSING WATER TEMPERATURE SET POINT
- WATER SIDE ECONOMIZER ENABLE POINT
- HORSE POWER FOR THE FAN/PUMPS
- ANY O&M CHALLENGE?

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 15

- This is the basic information you need to collect about the condensing water loop.
- Under "Specific", also need to collect OA dewpoint and OA wet bulb values.

CONDENSING WATER TEMPERATURE CONTROL

- NO TEMPERATURE RESET WHEN AMBIENT TEMPERATURE IS LOW



08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 16

- Dewpoint range is between 40 to 50°F. Reset temperature to a lower value to improve chiller efficiency—condenser water return temperature could be lowered to 65°F, when the dewpoint is low.
- Dew point requires OA humidity sensor and known barometric pressure to calculate in BAS.
- Wetbulb temperature requires OA humidity sensor and known barometric pressure to calculate in BAS.

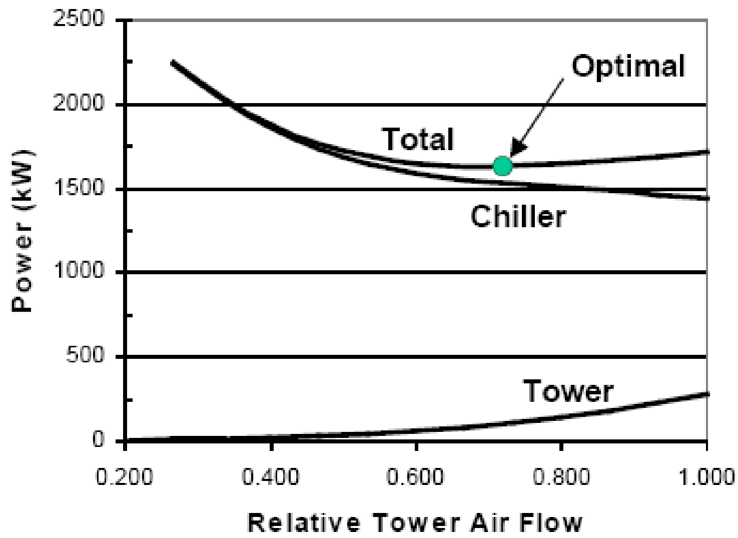
Re-Tuning Condensing Water Temperature Control

- Reset condensing water return temperature based on wetbulb temperature
- General guidelines:
  - Cooling tower return water temperature set point could be at least 5°F higher than ambient wetbulb temperature
  - This prevents excessive cooling tower fan power consumption
  - Cooling tower water return temperature should not be lower than 65°F for chillers made before 1999 and should not be lower than 55°F for newer chillers
  - Consult chiller manufacturer's manual for more information
- Cooling tower return water temperature reset can be implemented using BAS

08 Pre-Re-Tuning of Central Utility Plant, Slide 17

- This control strategy must be carefully applied in a foolproof manner because there are situations that could result in more energy usage if a simple control sequence is used.
- This is also why manual adjustment of condenser water temperatures as practiced by some facilities can be easily misapplied.
- More fan energy is required to provide the lower condenser water temperature; therefore, it is necessary to find the right balance for the greatest energy savings.
- It is even conceivable that with small chiller loads, the fan energy usage could be greater than the chiller energy savings if not properly compensated.

EXAMPLE OF TRADE-OFF



08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 18

- This graph shows the tower and chiller power. If the condenser temperature is low, it will lead to lowest possible point on total power curve.

BOILER AND HEATING SYSTEMS: COLLECTING BASIC INFORMATION

GENERAL

- BOILER CAPACITY, TYPE, AND NUMBER
- WATER LOOP RISER DIAGRAM
- VFD ON ANY PUMPS?

SPECIFIC

- BOILER ENABLE CONDITION
- HOT WATER TEMPERATURE SET POINT
- DIFFERENTIAL POSITION AND SET POINT IF INSTALLED

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 20

- This is the basic information to collect about the boiler and heating system.
- The "boiler enable" condition may be outdoor air temperature or other conditions.
- Under "Specific", also need to collect VFD pump speed, hot water supply and return temperatures and hot water valve command information.

DATA ANALYSIS

- ▶ REFER TO THE TREND LOG DATA ANALYSIS PROCEDURE

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 21

Review the procedure if needed.

Check for the following when analyzing the charges:

- The boiler is on during hot weather.
- No hot water supply temperature reset.
- No differential pressure reset for hot water pump control.

Boiler Lockout in Summer

- If boilers are only used for comfort heating, then consider shutting off the boiler during the summer

08 Pre-Re-Tuning of Central Utility Plant, Slide 22

- By reducing boiler use, you can avoid heating leakage and pumping cost.
- For example, if boilers are used to provide reheating for the terminal unit, they don't need to be on when outdoor air temperature is high (>70°F)
- By reducing boiler use, you can also reduce additional chiller cost from having to remove excess heat in the building from control valve leakage or other anomalies (poor controls, etc.) that allow for simultaneous heating and cooling.

DIFFERENTIAL PRESSURE SET POINT

- ISSUE: THE DIFFERENTIAL PRESSURE (DP) SET POINT FOR HOT WATER PUMP CONTROL IS TOO HIGH AT PARTIAL LOAD CONDITION
    - THE DP SET POINT IS A CONSTANT VALUE
    - THE HEATING COILING VALVES ARE FORCED TO CLOSE TO MAINTAIN THE DESIGN DP SET POINT AND THE HOT WATER PUMPS ARE OPERATED AT HIGH SPEED

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 23

- Bad example: The maximum heating coil value is less than 50% open; the hot water pump VFD is operated at high speed (>75%).
- A constant set point will always make it pump too hard. You want a variable set point based on valve position and outdoor air temperature.

Differential Pressure Set point (continued)

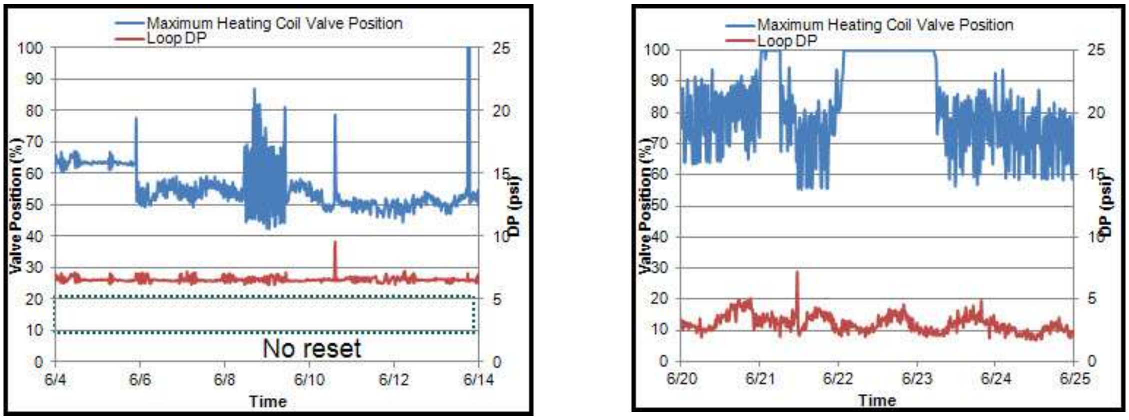
- Purpose:
  - Determine if the loop DP set point is constant
  - Determine the potential of resetting the DP to a lower value at partial load condition

08 Pre-Re-Tuning of Central Utility Plant, Slide 24

Approach:

- Review the plots of loop DP, maximum heating coil valve position vs. time.
- Check whether the DP is constant.
- Check whether the maximum heating coil valve position is less than 95%.

DIFFERENTIAL PRESSURE SET POINT EXAMPLE GRAPHS



08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 25

Example: Potential to reset the DP to a lower value at partial load condition.

- In the graph on the left, there is no reset. The differential pressure set point is at 7 psi (end of loop); maximum valve position is between 50 and 75% most of the time.
- In the graph on the right, DP reset is between 2.5 to 5 psi.

BOILER RE-TUNING PROCESS

- REDUCE THE BOILER STEAM PRESSURE AND HOT WATER TEMPERATURE
- BENEFITS:
  - IMPROVES PLANT SAFETY
  - INCREASES BOILER EFFICIENCY AND DECREASES SOURCE ENERGY CONSUMPTION
  - INCREASES CONDENSATE RETURN FROM BUILDINGS AND IMPROVES BUILDING AUTOMATION SYSTEM PERFORMANCE
  - REDUCES HOT WATER STEAM LEAKAGE THROUGH MALFUNCTIONING VALVES

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 26

- Most condensate tanks are open to mechanical rooms. When the steam pressure is decreased, secondary evaporation is significantly decreased, and mechanical room relative humidity is decreased.
- This also improves the humidity level of the compressed air provided to the pneumatic systems.
- For example, 5% hot water leakage at 180°F carries five times more energy into space than the same amount of water at 90°F.

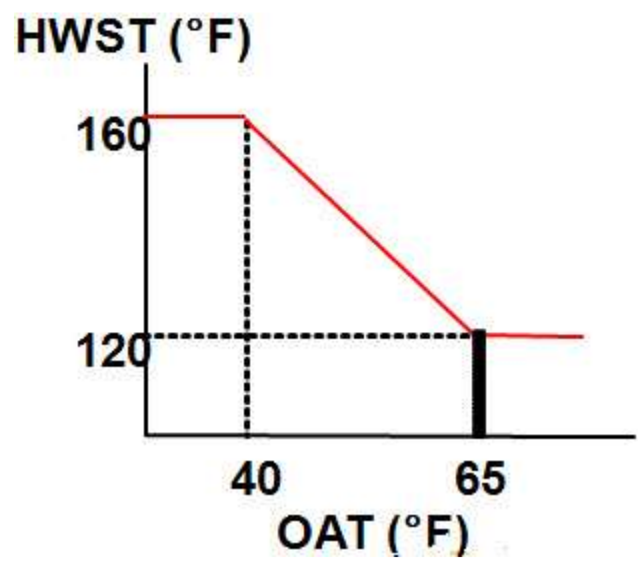
BOILER RE-TUNING PROCESS (CONTINUED)

- REDUCE HOT WATER SUPPLY TEMPERATURE SET POINT
- RESET HOT WATER SUPPLY TEMPERATURE DEPENDING ON BUILDING LOAD
- TYPICAL CONTROL RESETS SUPPLY HOT WATER TEMPERATURE BY OUTSIDE AIR TEMPERATURE

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 27

- If building loads are the only requirement for the hot water, then the hot water supply temperature can be reset according to the ambient temperature, time of day, or other appropriate scheduling variable.
- Maintain between 160°F and 180°F during winter.
- Maintain between 120°F and 140°F during summer.
    - Unless the boiler is a "condensing" boiler, temperature lower than 140°F are not recommended.

Linear Reset Schedule



08 Pre-Re-Tuning of Central Utility Plant, Slide 28

- This is an example of a linear reset schedule.
- When the outdoor air temperature is 65°F, the hot water set point should be 120°F.
- Push the system to the limit—you need to know your building to determine what that limit is.
- Hot water coil control valve position feedback can also be used to more aggressively reset the hot water loop down.

BOILER RE-TUNING PROCESS (CONTINUED)

- REDUCE STEAM PRESSURE SET POINT
  - INTERVIEW PERSONNEL WHO USE STEAM OR HOT WATER IN APPLICATIONS SUCH AS COOKING, CLEANING, AND MEDICAL USES TO DETERMINE THE HIGHEST STEAM REQUIREMENT
  - THE PLANT STEAM PRESSURE SHOULD BE THE SUM OF THE MAXIMUM REQUIRED END USE STEAM PRESSURE AND THE STEAM LOSS OF THE DISTRIBUTION SYSTEM

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 29

- For example, a typical medical building may have a steam pressure requirement of 40 psig. It is often supplied at 110 psig or higher.
- Pressure set point adjustment should be performed with care.
- For small boilers, it can be performed by simply adjusting the pressure switch.
- For large boilers, it involves complex control system and hardware adjustment. Consult the equipment manual.

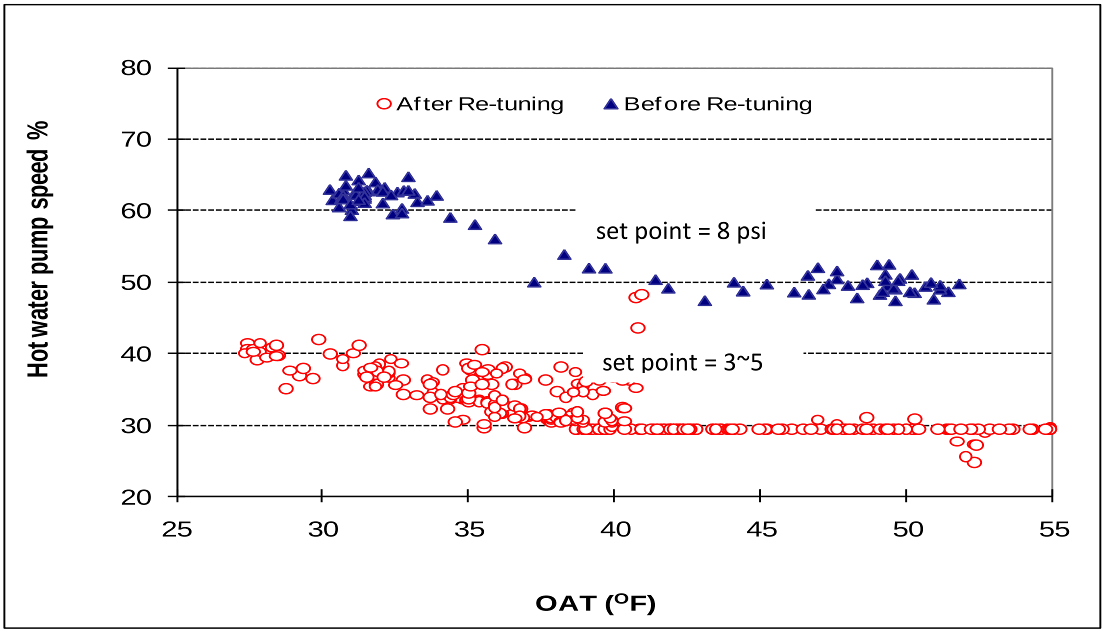
BOILER RE-TUNING PROCESS (CONTINUED)

- RESET THE LOOP DP SET POINT
  - IF THE MAXIMUM HEATING COIL VALVE IS LESS THAN 95% (CAN BE ADJUSTED ABOVE OR BELOW 95%) OPEN, DECREASE THE DP SET POINT 0.5 PSI (CAN BE ADJUSTED) EVERY 15 MINUTES (CAN BE ADJUSTED)
  - DETERMINE THE MINIMUM LOOP DP BASED ON SYSTEM CONFIGURATION AND COIL CONDITION

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 30

- Reduce loop differential pressure set point gradually at partial load condition.
- For example, if the DP sensor is installed across the remote cooling coil in the loop, the loop DP can be lowered to 3 psi.
- If the maximum heating valve opens to 100%, increase the loop DP set point to design value. This can be implemented in the building automation system. Use of dead band is recommended in this control.

BOILER RE-TUNING PROCESS (CONTINUED)



08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 31

- This graph shows hot water pump speed before and after differential pressure set point re-tuning.
- Can run as low as between 3 and 5 psig. Pump speed is reduced and doesn't have to work as hard. Comfort and flow are improved.

BOILER RE-TUNING PROCESS (CONTINUED)

- RESET THE BODY HEAT LOSS
  - HOT WATER BOILERS TYPICALLY STAGE ON/OFF TO MAINTAIN SUPPLY HOT WATER TEMPERATURE
  - OPTIMIZATION CONTROL

08 PRE-RE-TUNING OF CENTRAL UTILITY PLANT, SLIDE 32

- Frequent cycling increases loss to body/shell heat.
- Frequent cycling increases loss to stack because of pre-post purge cycles.
- Set boilers to operate on low fire most of the time to prevent frequent on/off cycling.
- Newer boilers are equipped with low/high fire settings.

O&M Tips for Steam and Condensate Return

- Steam traps
  - Check steam traps frequently. Steam traps have a tendency to fail, and leakage costs can be significant
- Condensate return
  - Inspect condensate return frequently

08 Pre-Re-Tuning of Central Utility Plant, Slide 33

- These are operation and maintenance tips.
- A steam trap maintenance program is recommended. Consult the manufacturer and manuals for proper procedures and methods.
- Collect condensate return as much as possible.
- Make sure that blow downs on traps are not left open or leaking.
- Make sure that traps located downstream of control valves or heating coils are cool to the touch, when the control valve is commanded to be closed. Otherwise, this could indicate a leaking control valve (if warm/hot to the touch). Recommend checking with an IR (infrared) gun to avoid skin burns.

Chapter 9: Building Walkdown

INSTRUCTOR GUIDANCE

TIME: 30 MINUTES

MATERIALS: POWERPOINT SLIDES 10 BUILDING WALKDOWN

LESSON GOAL: CONDUCT A THOROUGH BUILDING WALKDOWN

LEARNING OBJECTIVES:

- KNOW WHAT TO LOOK FOR IN MECHANICAL AND ELECTRICAL PRINTS
- KNOW WHAT TO LOOK FOR ON AND IN THE BUILDING'S EXTERIOR, INTERIOR, ROOF, AND PLANT AREA
- KNOW HOW TO USE THE BUILDING AUTOMATION SYSTEM TO COMPLETE THE WALKDOWN

BUILDING WALKDOWN: PURPOSE

- 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

09 BUILDING WALKDOWN, SLIDE 1

- The purpose of the building walkdown is to get to know the building and its systems better.
- By examining systems, talking to occupants and engineers, and taking measurements, you will get a good impression of the building's various systems and their conditions.

Building Walkdown: Major Steps

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

09 Building Walkdown, Slide 2

- Electrical and mechanical prints will enable you to identify electrical loads worth controlling, provide you with type of air handlers used, and provide you with the approximate number and size of perimeter and interior zones.
- Walking the outside of the building, examine windows, HVAC grills, doors, outside lights, and exterior outlets.
- Inside the building, examine lighting, hallways, perimeter and interior offices, and talk to tenants and the facility manager.
- On the roof, note HVAC equipment condition and examine exhaust fans and vents.
- Because air handlers are critical, you should examine most if not all air handlers.
- In the plant area, inspect pumps, chillers, boilers, cooling towers, and DDC controllers.
- When reviewing the building automation system, scan for offline points, alarms, and disabled code.

Review Electrical and Mechanical Prints

- Obtain electrical and mechanical prints
- Review mechanical prints
- Review Electrical prints

09 Building Walkdown, Slide 3

- When reviewing the mechanical prints, note the air handlers of each style (VAV or CV). Note the rough number and size of perimeter zones (one way to do this is to count the number of thermostats or the terminal box distribution). Note the number and size of the interior zones.
- When reviewing the electrical prints, identify the individual electrical loads potentially worth controlling—greater than 3.7 kW (> 5.0 hp). Record these loads in a table.

REVIEW ELECTRICAL AND MECHANICAL PRINTS (CONTINUED)

Equipment or System	Number	Load, kW	Comments
Air handling units (use one row for each size of air handler)			
Chillers (use a separate row for each chiller size)			
Lighting (List total lighting load or load by lighting circuit)			
Pumps (greater than 5 hp; use a separate row for pumps of each size and function)			
Exterior lighting (exterior of building, walkways, parking lots, etc.)			
Electric boilers (use a separate table row for each different electric boiler size)			
Ancillary loads (any other loads great than 3 kW; use a separate row for each different kind of load and size)			

09 BUILDING WALKDOWN, SLIDE 4

- This is an example of a table to use when recording information gleaned from the electrical and mechanical prints.

WALK THE OUTSIDE OF THE BUILDING

- WINDOWS
- GRILLS FOR HVAC SYSTEMS
- WEATHER DAMAGE AROUND WINDOWS AND DOORS

09 BUILDING WALKDOWN, SLIDE 5

- Examine windows. Purpose: Get a rough sense of the solar load on the perimeter zones
    - Estimate fraction of windows on each side of the building
    - Note the direction of each side of the building
    - Note the types of windows
    - If they can be opened, note what percentage of windows are open
    - Note any significant shading by side of the building.

- Examine HVAC grills. Purpose: Identify potential sources of ventilation problems
    - Estimate rough number of grills, their relative size, and their locations
    - Distinguish between large grills for HVAC and small exhaust grills
    - Note any HVAC intakes near sources of automotive exhaust and possible short circuits for air between exhaust air and intakes.

- Looks for weather-damaged caulking, cracks, and seals around windows and doors.

Walk the Outside of the Building

- Exterior doors
- Outside lights and parking lot lights
- Electrical outlets

09 Building Walkdown, Slide 6

- Examine exterior doors—Purpose: identify potential sources of excess infiltration or exfiltration
  - Estimate the number of doors, their locations, and their uses (e.g., main entrance, side entrance, service door, etc.)
  - Listen for air leakage around doors or poor or missing door seals along the edges and thresholds. Double doors should be sealed adequately between the two doors when they close.
  - Look for doors slamming shut or staying open—this may be lack of positive pressure or too much positive pressure.

- Examine outside lights, including parking lot lights
  - On during daylight hours
  - Excess electric loads.

- Note any exterior outlets with poor seals, poor caulking, or air noise.

- Note any piping penetrations into or out of the building (water, gas, electrical, etc.). These penetrations should be completely sealed.

WALK THE INSIDE OF THE BUILDING

- LIGHTING
- HALLWAYS

09 BUILDING WALKDOWN, SLIDE 7

- Examine interior lighting
  - Note type of lighting and kind of lamps predominantly used
  - Not directly related to re-tuning, but you could identify a simple, cost-effective re-lamping retrofit opportunity—for example, replace incandescent bulbs with CFL and replace T12 lamps and ballasts with high-efficiency electronic ballasts and T8 lamps.
- Inspect hallways
  - For each hallway, note whether it's comfortable, warm, or cool
  - Note whether hallways are warmer, cooler, or about the same temperature as the rooms they service
  - Note whether or not the hallways are over lit or lit to the same level as adjoining office spaces. If over lit, this could be an opportunity to de-lamp, as long as safety standards are not compromised.

Walk the Inside of the Building

- Perimeter offices
- Check one out of every few rooms by stepping in and observing
  - Type of heating
  - Discharge duct locations
  - Room temperature
  - Portable heaters used
  - Thermostat locations
  - Use of space
  - Corner offices
  - Lighting occupancy sensors
  - Occupants

09 Building Walkdown, Slide 8

- Type of heating.
- Discharge duct locations and whether registers are open, closed, covered with paper or cardboard, or treated in some other way
  - Measure the temperature of the discharge with an infrared (IR) gun.
- Measure the room temperature with IR gun by measuring the temperature of interior walls—take a few readings—and record them.
- Portable heaters used (look under desks).
- Thermostat locations—Purpose: Determine if location may influence over- or under-cooling or heating of a zone
  - Over heat sources, such as computer monitors
  - Behind shelves or other obstructions
  - Properly located, unobstructed on interior walls
  - Located in spaces served and not fighting with other zones caused by wall changes.
- Use of space—Note general use of space and any special ventilation or conditioning requirements
- Corner offices
  - Note if two walls have glass (potential source of extra load)
  - Note if corner offices are comfortable while nearby offices are not (corner office driving conditions).
- Lighting occupancy sensors
  - Check if they are used in each space
  - Note if any are hidden or blocked so they won't work.
- Occupants
  - Ask if they are comfortable or are frequently hot or cold
  - Ask building staff about excessive hot and/or cold complaints in particular rooms, zones, or hallways.

WALK THE INSIDE OF THE BUILDING

- INTERIOR OFFICES
- CHECK ONE OUT OF EVERY FEW ROOMS BY STEPPING IN AND OBSERVING
    - HEATING
    - DISCHARGE DUCTS
    - ROOM TEMPERATURE
    - PORTABLE HEATERS
    - THERMOSTAT LOCATIONS
    - USE OF SPACE
    - LIGHTING OCCUPANCY SENSORS
    - OCCUPANTS
    - NOISE

09 BUILDING WALKDOWN, SLIDE 9

- Note if there is any heating, and if so, what type, for interior zones. Note the heat source (duct heat from ceiling, wall radiators, forced air from walls, induction heat, radiant heat, etc.). Purpose is to determine whether heating is part of air handling system.
- Note locations of discharge ducts and whether they are open, closed, covered, etc. Measure the temperature of the discharge with an IR gun and record it.
- Use an IR gun to measure the air temperature of the walls in a few spots to get a rough average for the room and record it.
- Note any use of portable heaters (look under desks).
- Note if thermostats are located over heat sources, behind shelves or other obstructions, or are properly located on interior walls. The purpose is to determine if location may influence over- or under-cooling or heating of a zone.
- Note general use of space and any special ventilation or conditioning requirements.
- Ask occupants if they are comfortable or frequently hot or cold. Ask building staff about excessive hot and/or cold complaints in particular rooms, zones, or hallways. Talk to the owner or facility manager to get a sense of the types and volume of complaints over the course of a year.
- Listen for unusual noise from equipment or air flow—excessive air flow noise may indicate high duct static pressure.
- Look for un-insulated piping (steam, condensate return, hot water, chilled water, etc). Steam, condensate return and hot water lines that are run in plenum spaces (above drop ceilings) or in mechanical spaces add to the cooling loads seen by the air handlers and put additional loads on the heating systems (boilers, etc.).

WALKDOWN THE ROOF

- INSPECT HVAC EQUIPMENT TO DETERMINE CONDITION
- INSPECT EXHAUST FANS

09 BUILDING WALKDOWN, SLIDE 10

Examine HVAC equipment. Look for:

- Missing panels and seals around access doors
- Panels leaking
- Missing condenser fans
- General poor maintenance
- Other conditions that might affect performance.

Examine exhaust fans:

- Count or estimate the number of exhaust fans of each general size (small, medium, large)
- Verify fans are exhausting
- Large fans are candidates for control.

WALKDOWN THE AIR HANDLERS

- IDEALLY, YOU SHOULD INSPECT ALL AIR HANDLERS
- INSPECT AND RECORD THE FOLLOWING:
    - TYPE OF UNIT
    - VARIABLE FREQUENCY DRIVES
    - COILS, FILTERS, DAMPERS, BELTS, DOORS, AND VALVES
    - DDC CONTROLS
    - EXPOSED DUCTWORK IN MECHANICAL ROOM
    - NOISE
    - LOCATION OR OUTDOOR AIR SENSOR

09 BUILDING WALKDOWN, SLIDE 11

If there are a very large number of air handlers, a sample of between 50% and 75% should be adequate. Try to randomly sample different floors and disperse across low, mid-level, and high floors. If significant problems are found with the sample, all air handlers need to be inspected.

- Inspect and record type of unit (VAV, CV, single-zone, multi-zone)
- For VFDs, record speed on drive display and current time. Watch speed variation—you should see some. If there's no variation, it's probably overridden.
    - Open access door. VFD should modulate. No modulation indicates that it is probably overridden.
    - Check position of inlet vanes.
- Check for missing, dirty, plugged, or collapsed filters.
- Check for dirty or plugged coils.
- Inspect dampers and look for damage, missing mechanical connectors, leaking or missing seals, and/or and other obstructions (like 2 X 4s) between damper blades.
- Look for water leaks, valves leaking from packing, and/or valves not fully opening or not closing completely.
- Make sure isolation valves on working coils are wide open.
- Inspect DDC controls and look for disconnected wires, jumpers in place, switches in hand. Record all abnormal conditions.
- Inspect ductwork for gaps and leaks, holes in flex couplings, and vibrations.
- Note squeals (high air leakage from pinholes in ducts), thumping, or any uncommon fan sound (overload to extremely quiet).
- Note location of outdoor air sensor(s) – temperature and/or humidity. Make sure they are not falsely impacted by sun or man-made influences.

Walkdown the Plant Area

- Inspect the pumps
  - Determine and record whether each pump is running leaking, hot, or vibrating unusually
  - Record purpose of each system and parallel system
  - Record number of pumping systems running at the same time
  - For each pump, record pump speed for VFDs, running full speed or modulating, in override position

09 Building Walkdown, Slide 12

- Use visual observation and touch.
- If you can’t hold your hand on the pump, it’s too hot.
- Determine pump purpose: chilled water, hot water, condensate.
- Also record temperature and pressure of the water loops—pressure differences of more than 40 psi should be noted and investigated later.
- Make sure isolation valves on running pumps and pumps that are in service, are wide open.

Walkdown the Plant Area

- Inspect the chillers, boilers, and cooling towers
  - Record type of equipment, status, and general condition
  - Record number of units of each type running
  - Note chillers and boiler running at the same time
  - Inspect valves
  - Note systems in hand (manual override)
  - Record current loads

09 Building Walkdown, Slide 13

When inspecting valves, record

- Alignment (shaft position)—fully open, partially open or closed
- Automatic or manual control
- Water flowing when not needed
- Other unusual conditions.

Record current loads:

- Load on each unit running
- Temperature difference across unit.

Walkdown the Plant Area

- Inspect DDC controllers
  - Type and condition of DDC controls
  - Look inside the control panel

09 Building Walkdown, Slide 14

- While looking inside the control panel, record:
  - Disconnected wires
  - Jumpers in place
  - Switches in hand
  - All abnormal conditions.
- While walking down the plan, determine if a compressed air system exists in this area that provides compressed air to any pneumatic devices (thermostats, actuators, transducers, controllers, etc.). If true record:
  - Compressed air pressure
  - Air dryer functioning
  - Reduced pressure regulator setting (should be between 20 and 25 psi; any lower will affect controls).
  - Compressor run (on) time versus off time (should be close to 30% run (on) time versus 70% off time. If run time is higher, this could indicate undersized compressor, or significant system leaks (more likely) that need to be investigated/corrected.

Review the DDC (BAS) Front End

- Scan for and record
    - Offline points
    - Alarms
    - disabled code
- Verify accuracy of graphics
- Building electric meter

09 Building Walkdown, Slide 15

- Using the building automation system, scan for and record any points currently alarming.
- Scan for and record disabled code blocks.
- Make sure graphics are consistent with observations made during the walkdown.
- If the building meter is connected to the building automation system, turn on trending.
-

Chapter 10: Re-Tuning Building Controls and Systems

Instructor Guidance

Time: 15 minutes

Materials: PowerPoint Slides 11 Re-Tuning Controls and Systems

Lesson Goal: Re-tune your building based on specific findings

Learning Objectives:

- Understand that certain problems (no night/weekend setback, overridden schedules) can and should be corrected immediately.
- Understand that most re-tuning actions should be conservative (small changes over time)—there are no magic set points, and every building is different.

RE-TUNING CONTROLS AND SYSTEMS

- USING THE KNOWLEDGE LEARNED FROM TREND-DATA ANALYSIS AND BUILDING WALKDOWN TO START THE RE-TUNING PROCESS

10 RE-TUNING CONTROLS AND SYSTEMS, SLIDE 1

- Based on trend graphs, the building walkdown, and interviews with occupants and building operators, we are now ready to begin re-tuning.
- As part of re-tuning, the technician corrects problems that are detected and can be corrected immediately (e.g., change schedules, release overridden points). The technician also records a list of detected problems that could not be immediately corrected, such as repairs or replacement of equipment or other changes that require decision/approval by the building manager or owner.

COMMON ASSUMPTIONS

- OFTEN, RESISTANCE MAY BE ENCOUNTERED WHEN PROPOSING THAT A BUILDING NEEDS RE-TUNING:
    - "SYSTEMS ARE WORKING NORMALLY AND NO REPAIRS ARE REQUIRED"
- AS YOU WORK THROUGH THE RE-TUNING PROCESS, YOU LIKELY WILL FIND A LOT OF MECHANICAL AND SOFTWARE ITEMS THAT NEED FURTHER ATTENTION

10 RE-TUNING CONTROLS AND SYSTEMS, SLIDE 2

- When you propose that a building may need re-tuning, you will often encounter building managers, operators, and engineers who say that all systems are working normally and no repairs are needed. This is invariably a false assumption. All buildings have broken and bypassed systems.
- Document items that need further attention (items that are not no-cost/low-cost) and handle them with the building owner/operators.

NOTE TO INSTRUCTOR:

The PNNL Building Re-Tuning instructors generate trend graphs for the site where they are conducting the training. You should take the same approach and generate (and teach to) slides based on the building you and your students are re-tuning. One way to do this is to generate trend graphs after the walkdown but before re-tuning, have students make some adjustments, and then generate new, after-re-tuning adjustments.

CONCLUSIONS

- YOU **CAN** SAVE ENERGY AND KEEP STAFF COMFORTABLE.
- IT TAKES TIME TO TUNE A BUILDING.
- THERE ARE NO MAGIC SET POINTS THAT WILL WORK ALL THE TIME.
- ALWAYS MONITOR THE UTILITY METERS (GAS AND ELECTRIC) TO SEE WHAT EFFECT YOU HAVE HAD.
- LOOK AT THE BIG PICTURE WHEN MAKING ADJUSTMENTS.
- LEARN AND KNOW YOUR BUILDING'S PERSONALITY

10 RE-TUNING CONTROLS AND SYSTEMS, SLIDE 3

- The trend graphs in the previous slides focused on [AHU, zone terminal boxes, chillers, cooling towers, boilers, and pumps]. You will need to generate additional trend graphs based on the knowledge gained through the building walkdown to implement complete, high-quality re-tuning.
- Every set point adjustment you make will have an impact of some sort on the utility meter.
- Make small, incremental changes over time.
- Consider the climate, the season, and other environmental factors when starting a re-tuning project.
- Watch meter profiles weekly.
- Every building has its own personality—get to know yours.
- Basic energy management:
    - If you don't need it, turn it off
    - If you don't need it at full power, turn it down
    - Make energy systems smart, adjusting to real needs.

Appendix A - Monitoring Plans (handouts)

To create a monitoring plan, specify the points to be monitored for each system, the time interval between measurements and the time period over which each point will be monitored.

The following guidance is for buildings with variable air volume (VAV) systems and a central plant with chiller/boiler.

For the VAV system: Select the air handling units (AHUs) to be monitored and the points on each AHU to be monitored following this guidance:

1. If there are six or fewer AHUs in the building, monitor all the AHUs.
2. If the building is three-stories or less in height, select at least one AHU for each floor.
3. If the building has more than six AHUs, select at least half of them for monitoring, distributing them among the floors of the building.
4. Do not pick the AHUs that are operating "best." Try to select the AHUs randomly, or select ones that you think are operating about average for the building.
5. For buildings with one or more basements, monitor at least one AHU serving a basement floor.
6. Always monitor an AHU for the first floor of the building.

Some examples of selecting AHUs for monitoring follow.

Three-story building with two AHUs serving each floor.
Monitor all six AHUs.

Twenty-story building with one basement and one AHU per floor.
Monitor the AHUs serving the basement and the first floor, plus the AHUs serving floors 3, 5, 7, 9, 11, 13, 15, 17 and 19, for a total of 11 AHUs monitored.

400,000-square foot, two story building with 1 basement and 1 AHU for each 20,000 square foot of floor space for a total for 20 AHUs.

Monitor 12 AHUs, 4 for the basement and 4 for each of the 2 above-ground floors.

18-story office building, with 2 sub-basements and two AHUs per floor (including the basements).
There are a total of forty AHUs. Twenty of these should be monitored. One solution would be to select one from each of the floors, including the two basements.

36 story office building served by three large AHUs.
Because there are fewer than six AHUs, monitor all of them.

For each AHU set up trend logs for the following data points measured at 30-minute intervals for a 2-week period:

1. Outdoor-air temperature
2. Mixed-air temperature
3. Return-air temperature
4. Discharge-air temperature

5. Discharge-air temperature set point
6. Discharge static pressure
7. Discharge static pressure set point
8. Mixed-air damper position
9. Return-fan status (if a return fan is present)
10. Return-fan speed or vortex damper position (if a return fan is present)
11. Supply-fan status
12. Supply-fan speed or vortex damper position
13. Cooling-coil valve position
14. Heating-coil valve position
15. Occupancy mode of the AHU (i.e., occupied or unoccupied).

For the VAV Boxes and Zones: Select the VAV boxes to be monitored and the points on each to be monitored following the guidance that follows.

1. Where possible, select zones to monitor that are served by the AHUs selected for monitoring.
2. If there are eight or fewer zones per floor, set up trend logs for all zones on a floor.
3. For buildings with 10 or fewer floors, monitor zones on each floor.
4. For buildings with more than 10 floors, monitor zones on every other floor.
5. For each floor, set up a trend log for at least one perimeter zone on each of the four directions (e.g., north, south, east and west) and for at least four zones in the core. This will result in at least eight VAV boxes being monitored per floor.

Extending monitoring for the example buildings given for selection of AHU, the following examples are provided for selecting zones and VAV boxes to monitor.

> *Three-story building with two AHUs serving each floor. Each floor has six zones, four perimeter zones and two core zones.*
>
> Set up trend logs for all zones because the building 10 or fewer floors, and each floor has only six zones.
>
> *Twenty-story building with one basement and one AHU per floor. Each floor has eight perimeter zones, with two facing each cardinal direction and four core zones.*
>
> AHUs for the basement and floors 1, 3, 5, 7, 9, 11, 13, 15, 17 and 19 were selected for monitoring the AHUs. Select the same floors for monitoring the zones. For each of these floors, set up logs for one of the exterior zones facing each of the cardinal directions and all four of the core zones. That will provide 8 zones per floor over 10 floors for a total of 80 zones monitored (out of the total of 240 zones in the building).
>
> *400,000-square foot, 2-story building with one basement and one AHU for each 20,000 square foot of floor space for a total for 20 AHUs. The building is irregularly shaped but all exterior walls face one of the four cardinal directions, east, west, north, or south. There are 4 zones per AHU for a total of 80 - 40 of these are exterior zones, and 40 are core zones. There are 30 zones for each of the above-ground floors and 20 zones for the basement.*

Following the guidance for buildings with fewer than four floors, zones on all floors should be monitored. Eight zones are selected from each floor, including the basement, 4 serving core zones and 4 serving exterior zones with each of the exterior zones being on a wall facing a different cardinal direction, for a total of 24 zones monitored (out of a total of 80 zones in the buildings). All of the zones are served by 1 of the 12 air handlers being monitored.

18-story office building, with two sub-basements and two AHUs per floor (including the basements). Each floor has twelve exterior zones and 6 interior zones.

Because the building has more than 10 floors, zones on every other floor can be monitored. Therefore, we might select to monitor zones for one of the basements and floors 1, 3, 5, 7, 9, 11, 13, 15, and 17. On each floor selected to monitor zones, one exterior zone is selected for each of the four exterior walls and four of the interior zones. Because only one AHU was selected for monitoring on each floor of the building, many of the zones selected for monitoring are not served by a monitored AHU.

36-story office building, served by three large AHUs. There are eight perimeter zones per floor, two facing each cardinal direction, and four core zones.

All of the AHUs are monitored, so any zone selected will be served by a monitored AHU. Because the building is over 10 stories tall, zones from only every other floor need to be monitored. Because the first floor must be monitored, floors 1, 3, 5, … 33, 35 are selected. For each of these floors, one exterior zone facing each cardinal direction is selected as are half of the core zones. With one VAV box per zone, this leads to 144 VAV boxes selected for monitoring (out of a total of 432).

For each zone selected for monitoring, trend logs should be set up for the following points with measurements logged every 30 minutes for a 2-week period:

1. Zone temperature
2. Zone set point temperature
3. VAV box damper position
4. Reheat valve position (if supply air is reheated at the zone by hot water)
5. Occupancy mode (occupied/unoccupied).
6. VAV box cfm set point
7. VAV box cfm

The VAV box and zone section of the monitoring plan can be prepared by completing the template shown in tables that follow. A table also shows a completed example form for the example two-story building with two AHUs and six zones per floor.

Air-Handling Unit Monitoring Plan Template

Building Name:	
Building Location:	
Date:	

Re-Tuning Technician Name:	
Contact Information:	

Floor:	
Equipment Name:	

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units

Floor:	
Equipment Name:	

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units

Floor:	
Equipment Name:	

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units

Repeat tables as necessary, one for each air handling unit.

Example of Completed Air Handling Unit Monitoring Plan

Building Name:	ABC Bank Building
Building Location:	123 4th Ave., Seattle, WA 99111
Date:	April 3, 2007

Re-Tuning Technician Name:	John Doe, McDonalds Control Services
Contact Information:	(509)555-5555; john.doe@mcs.com

Floor:	1
Equipment Name:	AHU-1

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
OAT1	Outdoor air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
MAT1	Mixed air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
RAT1	Return air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
DAT1	Discharge air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
PDIST1	Discharge Static Press	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	psi
MADamper1	Mixed air damper position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
Fan1	Fan status	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	on/off

Fan Speed1	Fan speed	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	rpm
CWV%1	Chilled water valve position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
HWV%1	Hot water valve position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
MODE1	Occupancy mode	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Occupied/ Unoccupied

Floor:	2
Equipment Name:	AHU-2

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
OAT2	Outdoor air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
MAT2	Mixed air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
RAT2	Return air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
DAT2	Discharge air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
PDIST2	Discharge Static Press	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	psi
MADamper2	Mixed air damper position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open

Fan2	Fan status	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	on/off
Fan Speed2	Fan speed	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	rpm
CWV%2	Chilled water valve position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
HWV%2	Hot water valve position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
MODE2	Occupancy mode	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Occupied/ Unoccupied

Air-Handling Unit Monitoring Plan Template

Building Name:	
Building Location:	
Date:	

Re-Tuning Technician Name:	
Contact Information:	

Floor:	
Equipment Name:	

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units

Floor:	
Equipment Name:	

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units

Floor:	
Equipment Name:	

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units

Repeat tables as necessary, one for each VAV box/zone.

Example of Completed Zone/VAV Box Monitoring Plan Template

Building Name:	ABC Bank Building
Building Location:	123 4th Ave., Seattle, WA 99111
Date:	April 3, 2007

Re-Tuning Technician Name:	John Doe, McDonalds Control Services
Contact Information:	(509)555-5555; john.doe@mcs.com

Floor:	1
Equipment Name:	VAV1-1

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
T1-1	Zone air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
TSP1-1	Zone air temperature set point	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
VAV%1-1	VAV box damper position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
REHEAT%1-1	VAV box reheat valve position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
MODE1-1	Zone occupancy mode	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Occupied/ Unoccupied

Floor:	1
Equipment Name:	VAV1-2

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
T1-2	Zone air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
TSP1-2	Zone air temperature set point	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
VAV%1-2	VAV box damper position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
REHEAT%1-2	VAV box reheat valve position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
MODE1-2	Zone occupancy mode	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Occupied/ Unoccupied

Floor:	2
Equipment Name:	VAV2-1

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
T2-1	Zone air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F

TSP2-1	Zone air temperature set point	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
VAV%2-1	VAV box damper position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
REHEAT%2-1	VAV box reheat valve position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
MODE2-1	Zone occupancy mode	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Occupied/ Unoccupied

Floor:	2
Equipment Name:	VAV2-2

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
T2-2	Zone air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
TSP2-2	Zone air temperature set point	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
VAV%2-2	VAV box damper position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
REHEAT%2-2	VAV box reheat valve position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
MODE2-2	Zone occupancy mode	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Occupied/ Unoccupied

Floor:	3
Equipment Name:	VAV3-1

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
T3-1	Zone air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F

TSP3-1	Zone air temperature set point	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
VAV%3-1	VAV box damper position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
REHEAT%3-1	VAV box reheat valve position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
MODE3-1	Zone occupancy mode	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Occupied/ Unoccupied

Floor:	3
Equipment Name:	VAV3-2

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
T3-2	Zone air temperature	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
TSP3-2	Zone air temperature set point	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Degrees F
VAV%3-2	VAV box damper position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
REHEAT%3-2	VAV box reheat valve position	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	% open
MODE3-2	Zone occupancy mode	5/1/07 TBD	5/15/07 TBD	2 weeks	30 min	Occupied/ Unoccupied

For the physical plant: Set up trend logs for the following points at 30-minute intervals for a 2-week period:

1. Chilled-water supply temperature
2. Chilled-water return temperature
3. Hot-water supply temperature
4. Hot-water return temperature
5. Condenser supply temperature (temperature of water from the cooling tower)
6. Condenser return temperature for each chiller (leaving the condenser)
7. Load on each chiller
8. Status of each pump (if there are multiple pumps, record the status of all of them)
9. Status for each chiller (if chiller load is recorded this point may not be needed).

A template for the physical plant section of the monitoring plan is provided in below.

Whole-building electric consumption: If whole-building electricity use is monitored by the building automation system, trend the consumption (in kWh or average kW) at 5-minute intervals for a 2-week period.

Implementing the Monitoring Plan

After the monitoring plan is developed, the technician implements the trend logs specified by the plan in the building automation system (BAS). The specific procedures for implementing trend logs vary across BASs and are, therefore, not described here. If the technician does not know how to implement trend logs in the BAS, the onsite BAS expert or contractor should be consulted for assistance with setting up trend logs.

After completing trend log set up, the sequence of operations currently programmed should be reviewed and snapshots of current system conditions should be printed and saved.

Physical Plant Monitoring Plan Template

Building Name:	
Building Location:	
Date:	

Re-Tuning Technician Name:	
Contact Information:	

Mechanical Room Location:	

Equipment Name	Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planned Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
Chiller Plant	CWST	Chilled water supply temperature					
Chiller Plant	CWRT	Chilled water return temperature					
Chiller Plant	CNDST	Condenser supply temperature (temperature of water returning from the cooling tower)					
Hot Water Plant	HWST	Hot water supply temperature					

Hot Water Plant	HWRT	Hot water return temperature					

Chillers: Create a table for each chiller in the physical plant.

Chiller 1	CHLOAD1	Chiller 1 load					
Chiller 1	CHSTAT1	Chiller 1 status (only needed if load is not available)					
Chiller 1	CNDRT1	Condenser return temperature (temperature of water leaving the condenser)					

Chiller 2	CHLOAD2	Chiller 1 load					
Chiller 2	CHSTAT2	Chiller 1 status (only needed if load is not available)					
Chiller 2	CNDRT2	Condenser supply temperature (temperature of water leaving the condenser)					

Pumps: Create a row for each pump

Pump 1	P1-STATUS	Status of Pump 1					
Pump 2	P2-STATUS	Status of Pump 2					
Pump 3	P3-STATUS	Status of Pump 3					

Appendix B - Air Handler Unit Operations & Maintenance Checklist (handout)

- ☐ Is damper linkage connected?
- ☐ Do damper actuators actually operate?
- ☐ What condition are the damper blades in?
- ☐ Are minimum positions being maintained?
- ☐ Are VFDs actually working?
- ☐ Are inlet vanes operable?
- ☐ Is simultaneous heating and cooling occurring?
- ☐ Is sequential heating and cooling taking place?