PNNL-SA-92792

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Instructor Manual: Re-tuning Small Commercial Buildings

S Katipamula
RM Underhill
JK Goddard
D Taasevigen

April 2013

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

DISCLAIMER

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

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[2,3]. While sophisticated energy management and control systems are used in large commercial buildings to manage heating, ventilating, and air conditioning systems and components, most small commercial buildings (<100,000 sq. ft.) do not have these systems, increasing the difficulty to properly commission, operate and maintained these buildings. 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 identify energy savings opportunities and implement improvements. Re-tuning is a systematic process to identify operational problems in buildings without a 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. While most of these re-tuning training sessions were focused on the large commercial buildings, in 2012, PNNL developed the re-tuning training for small commercial buildings without BASs. 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 the Small 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 the Small Building Re-tuning Course

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

- onsite employees responsible for day-to-day building operations,

[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.

[3] 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.

- 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.

The focus is on small (<100,000 sq. ft.) commercial buildings (small office buildings, retail stores, etc.) without building automation systems.

Intended Audience for the Small 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 small building 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: Investigation Phase: Building Walk-Down
    a. Purpose of a building walk-down
    b. List the different systems and components that need to be focused on
5. Chapter 5: Investigation Phase: Building Envelope

    a. What to focus on when reviewing windows and doors
    b. What to focus on when reviewing walls and roofs
6. Chapter 6: Investigation Phase: HVAC Systems and Controls
    a. What to focus on when reviewing packaged equipment
    b. What to focus on when reviewing thermostat controls
    c. Using the senses (visual, audio, feel, smell) to detect problems
7. Chapter 7: Investigation Phase: Lighting Systems and Controls
    a. What to focus on when reviewing interior and exterior lighting
8. Chapter 8: Investigation Phase: Hot Water Systems and Controls
    a. What to focus on when reviewing domestic and heating hot water systems
9. Chapter 9: Investigation Phase: Office Equipment
10. Chapter 10: Investigation Phase: Indoor Environmental Quality
11. Chapter 11: Investigation Phase: Air Distribution Systems
12. Chapter 12: Implementation Phase: Building Envelope
    a. What to focus on when improving doors, windows, walls and roofs
13. Chapter 13: Implementation Phase: HVAC Systems and Controls
    a. What to focus on when improving HVAC RTUs and controls
14. Chapter 14: Implementation Phase: Indoor Condition
    a. What to focus on that may be impacting indoor conditions
    b. What to focus on when improving indoor conditions
15. Chapter 15: Implementation Phase: Lighting Systems and Controls
    a. What to focus on when improving lighting and controls
16. Chapter 16: Implementation Phase: Hot Water Systems and Controls
    a. What to focus on when improving hot water systems and controls
17. Chapter 17: Implementation Phase: Air Distribution Systems

a. What to focus on when improving air distribution systems

18. Chapter 18:Meter Data Profile Analysis

    a. How to analyze building meter data (if available)

19. Chapter 19: Documentation Phase and Calculated Savings

    a. How to document the measures implemented and calculate savings

20. Chapter 20: Conclusions

Small 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[4]. The project website's URL www.pnnl.gov/buildingretuning includes the following re-tuning resources:

- the most up-to-date instructor's manual,
- Building walk-down 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 and the slides 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.

[4] The DOE Building Technologies Program's Workforce Training website also has a number of useful resources - http://www1.eere.energy.gov/buildings/commercial/workforce.html.

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 SMALL BUILDING RE-TUNING
- DEFINE RE-TUNING

Purpose of Class

- Provide an in-depth overview of the re-tuning method
- Increase knowledge and skill sets of employees
- 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

Instructor Notes

- The purpose of the training delves into various aspects of "how-to" maintain (and sustain) building systems, "how-to" identify problems and areas for improvement, and "how-to" make a building and its individual systems more energy-efficient.

- The knowledge and skills learned by anyone who seriously applies the concepts delivered in this training will lead to job opportunities for those who are proficient. For students who diligently apply these concepts, there will be opportunities to find employment by organizations and companies who recognize the value these potential employees bring.

- For those who are already employed, this training will provide skills and capabilities that will set them apart for promotion and/or job security where employers understand the economic value of finding no/low cost improvements from re-tuning processes.

- This training can be used by anyone who deals with small- or medium-sized buildings. Besides students or technicians, this may also include building owners or building engineers, but the most likely users of this training are students and technicians.

- Hands-on field training re-enforces the classroom concepts. Concepts rarely move from theory to real-world application without repeated demonstration.

- More background: Re-tuning was originally developed as part of a project funded by Washington State (www.retuning.org). PNNL then extended training outreach beyond Washington State (www.pnnl.gov/buildingretuning).

INTENDED AUDIENCE

- ONSITE EMPLOYEES RESPONSIBLE FOR DAILY OPERATIONS
- JANITORIAL/CUSTODIAL STAFF
- OFFSITE CONTRACTORS HIRED TO IMPROVE A BUILDING'S ENERGY EFFICIENCY
- INDIVIDUALS INTERESTED IN THIS FIELD OF STUDY

01 INTRODUCTION TO CLASS

- Might include building owners or responsible engineering staff
- Might include retro-commissioning agents, service providers and control vendors
- Might include community college students, 4-year college students and military veterans
- Re-tuning is and will continue to be the new frontier of building operations. Re-tuning skills can be developed in almost any job skill set, from custodial staff all the way to engineers.
- As budgets reduce, resource-challenged organizations will be looking to leverage employee skill sets in areas that improve operational efficiencies in all areas (energy reductions, reduced occupant complaints and extended equipment life).

DEFINITION AND SCOPE

- SYSTEMATIC PROCESS
- IDENTIFY AND CORRECT PROBLEMS
- PRESCRIPTIVE PROCESS
- NOT RELIANT ON MONITORED BAS DATA
- PACKAGED UNIT (RTU) HVAC FOCUS
- SIMILAR CONCEPTS TO RETRO-CX
- WHOLE BUILDING ENERGY END USE (ELECTRICITY AND GAS) DATA ANALYSIS

01 INTRODUCTION TO CLASS

- Building re-tuning is a systematic process to identify and correct operational problems that lead to energy waste
- Typically, re-tuning relies on data analysis from building automation systems (BASs). This training is targeted toward buildings without BASs, therefore lacking trended data.
- Data analysis does not require or rely upon direct observation of equipment performance. Therefore, this type of training will require more "hands-on" observation and prescriptive analysis.
- There are many types of packaged units used for heating and cooling with simple air distribution (including rooftop units). 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.
- Zone thermostats drive the system and can have a ripple effect all the way to the meter.
- 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.

Approach

- Building re-tuning is normally a systematic process to identify and correct operational problems that lead to energy waste
- Re-tuning for large commercial buildings is reliant upon data from building automation systems to identify operational problems. Because many small/medium sized buildings do not have this capability, the process will be prescriptive and not reliant upon detailed monitored data and will use a four step approach

Step 1 - Initial data collection phase – collect information about the building

Step 2 - Investigation phase – building walk-down to identify/characterize the building

Step 3 - Implementation phase – application of prescriptive re-tuning measures

Step 4 - Documentation phase – report measures implemented and calculation of energy savings

01 Introduction to Class

- Each of these phases will require careful documentation skills. Trainees need to have good documentation skills, along with a correct technical foundation to accurately document findings, observations and implemented changes.
- As electronic tools are further developed or utilized, it would not be uncommon to expect pictures, infrared thermal images, portable data logger files (temperatures, power consumption, etc.) and other electronic data to become part of this data set.
- Other maintenance-related issues include the condition of filters, coils, duct air leaks, door and window seals, insulation, building envelope integrity, and many other related topics will be discussed or identified as part of the re-tuning focus.
- Re-tuning can be thought of as scaled-down retro-commissioning focused on identifying and correcting operational problems.

MAJOR FOCUS AREAS

- BUILDING ENVELOPE
- HEATING, VENTILATION AND AIR CONDITIONING SYSTEMS AND CONTROLS
- PACKAGED AIR CONDITIONERS, HEAT PUMPS AND GAS FURNACES
- LIGHTING AND LIGHTING CONTROLS
- HOT WATER
- OFFICE EQUIPMENT
- INDOOR ENVIRONMENTAL CONDITIONS
- AIR DISTRIBUTION SYSTEMS
- METER PROFILE

01 INTRODUCTION TO CLASS

- Process equipment is not the major focus.
- Although the focus area includes office and process equipment, specialized (manufacturing-related) equipment will not be a significant part of this course – unless the instructor chooses to add additional materials related to specific process equipment.
- Some of these focus areas will require that trainees, technicians and others apply caution and pay attention to safety when collecting data, investigating or implementing changes. Any electrified equipment, gas-fired equipment, rotating equipment or high temperature systems could cause serious injury or death.
- A healthy respect for all mechanical and electrical systems is at the heart of any organization that values students or employees.
- Other hazards may be unexpected, but should be part of anyone's "awareness" as they walk-down a building (roof access, ladders – falling from heights), exposed wiring, high temperature hazards, gas leaks, rodents, snakes, spiders or any other unexpected hazard (natural or man-made).
- It is always wise to communicate with facility managers and building owners prior to performing any building or system evaluation/walk-down. At a minimum, they should be aware of what you will be doing (equipment to observe and review), so they are aware of your plans. This is also important for your own safety in case you are hurt, and fail to report back when you indicated you would.

SCOPE

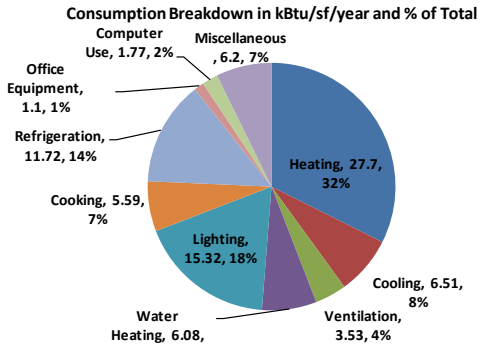
- SMALL-SIZED BUILDINGS
- MEDIUM-SIZED BUILDINGS
- FOCUS ON LOW-COST AND NO-COST IDEAS AND METHODS FOR SAVING ENERGY
- A PRESCRIPTIVE APPROACH TO IDENTIFY AND CORRECT BUILDING OPERATIONAL PROBLEMS
- MAY INCLUDE IDENTIFICATION OF OTHER OPPORTUNITIES THAT REQUIRE INVESTMENT

01 INTRODUCTION TO CLASS

- Small-sized buildings are defined as < 25,000 sf and no building automation systems.
- Medium-sized buildings are defined as > 25,000 sf and generally < 100,000 sf and no building automation systems.
- If the student or building technicians work in a small or medium-sized building that does have a building automation system, please consult with the PNNL large building re-tuning training for further training information.
- Examples of this include installation of low-cost weather-stripping on doors, sealing exterior wall piping penetrations, fixing photo-cells for exterior lights, thermostat adjustments or other similar ("key pad", "key stroke" or manual-auto switch adjustments) to effect more efficient building operations.
- Care must be exercised to mitigate inadvertent impact to facilities or facility systems that serve critical spaces or could be deemed "Mission-Critical."

SCOPE

- SMALL-SIZED COMMERCIAL BUILDING CHARACTERISTICS
- BUILDINGS LESS THAN 25,000 SQUARE FEET (SF)
    1. PERCENT OF TOTAL NUMBER OF COMMERCIAL BUILDINGS – 54%
    2. PERCENT OF TOTAL COMMERCIAL BUILDING SQUARE FOOTAGE – 22%
    3. PERCENT OF TOTAL COMMERCIAL BUILDING ENERGY USE – 21%
- EVEN A 10% REDUCTION IN HVAC AND LIGHTING ENERGY CONSUMPTION WILL LEAD TO 6 KBTU/SF/YEAR OR 150 MBTU/YR FOR A SMALL COMMERCIAL BUILDING

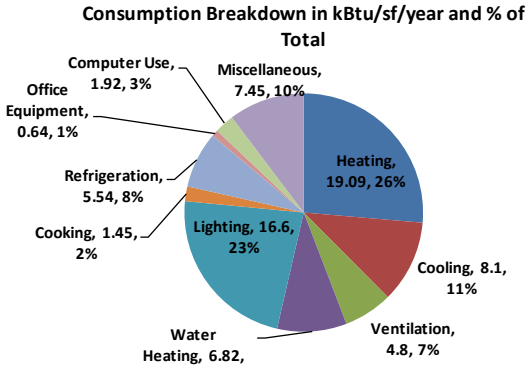


01 INTRODUCTION TO CLASS

- In most small commercial buildings, lighting and heating systems account for 50% of the total energy consumption.
- In southern climate zones, cooling systems may account for more energy consumption than heating systems.
- Therefore, the focus should obviously be on these systems or others that offer the greatest opportunities related to low-cost and no-cost improvements.

SCOPE

- MEDIUM-SIZED COMMERCIAL BUILDING CHARACTERISTICS
- BUILDINGS GREATER THAN 25,000 SQUARE FEET AND UP TO 50,000 SQUARE FEET
    1. PERCENT OF TOTAL NUMBER OF COMMERCIAL BUILDINGS – 3%
    2. PERCENT OF TOTAL COMMERCIAL BUILDING SQUARE FOOTAGE – 6%
    3. PERCENT OF TOTAL COMMERCIAL BUILDING ENERGY USE – 5%
- EVEN A 10% REDUCTION IN HVAC AND LIGHTING ENERGY CONSUMPTION WILL LEAD TO 5.5 KBTU/SF/YEAR OR 275 MBTU/YR FOR A MEDIUM COMMERCIAL BUILDING THAT IS 50,000 SF IN SIZE



01 INTRODUCTION TO CLASS

- In most medium commercial buildings, lighting and heating systems account for 49% of the total energy consumption.
- In southern climate zones, cooling systems may account for more energy consumption than heating systems.
- Therefore, the focus should obviously be on these systems or others that offer the greatest opportunities related to low-cost and no-cost improvements.
- Process-heavy (industrial or manufacturing) buildings may have a different makeup of energy consumption, which may impact the approach used in re-tuning for those types of buildings.

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'S PERSONALITY AND THEN MAKING INCREMENTAL ADJUSTMENTS TO ACHIEVE MORE DESIRABLE RESULTS

NOTE: THIS SECTION IS OPTIONAL FOR THE INSTRUCTOR

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.

02 BUILDING PERSONALITY

AT IS RE-TUNING – BASIC ENERGY MANAGEMENT PRINCIPLES

- IF YOU DON'T NEED IT, TURN IT OFF.
- IF YOU DON'T NEED IT AT FULL POWER, TURN IT DOWN.
- MAKE SMART ENERGY DECISIONS WHEN ADJUSTING SYSTEMS TO THE REAL NEEDS
- KNOW YOUR BUILDING'S PERSONALITY (HOW IT RESPONDS TO INTERNAL AND EXTERNAL LOADS)
- SAVE ENERGY WITHOUT NEGATIVELY IMPACTING OCCUPANT COMFORT

02 BUILDING PERSONALITY

- This is just basic energy management.
- Keep these concepts in mind through the entire re-tuning process.
- Often overlooked in this effort is the optimization of equipment, resulting in extended equipment life, which has a positive outcome for delay of capital equipment replacement.
- Saving energy while maintaining occupant comfort (or actually improving occupant comfort), is the goal when dealing with HVAC systems in small- or medium-sized buildings.

AT IS RE-TUNING – UNDERSTANDING BUILDING PERSONALITY PRINCIPLES

- BUILDINGS START AS CHILDREN
  - DESIGNED (BY PARENTS)
    - BY ENGINEERS WITH BEST GUESS INFORMATION
    - FOR SOME WEATHER CONDITIONS, INSIDE LOAD CONDITIONS
    - FOR A SPECIFIC NUMBER OF OCCUPANTS
    - FOR A SPECIFIC SOLAR GAIN AND ORIENTATION
  - BUILT WITH (CHILDHOOD YEARS)
    - LOW BID
    - TIGHT SCHEDULES
    - LIMITED INSPECTIONS, MINIMUM OR NO COMMISSIONING

02 BUILDING PERSONALITY

- "Value" engineering often reduces design, installation and startup costs, but can come with increased operating costs (including energy) over the life of the building.
- "Value" engineering can reduce cost, but this may result in minimal code required design components and efficiencies, resulting in less capability and value to the owner and occupants over the life of the building (increased life-cycle cost) in both energy and maintenance.
- In the rush to get a building constructed and occupied, design or installation problems may be overlooked or brushed aside. This results in more "challenges" for the operations and maintenance staff.
- Configuration of heating and cooling systems may have never been properly configured from the start of the building.

AT IS RE-TUNING – UNDERSTANDING BUILDING PERSONALITY PRINCIPLES (CONTINUED)

BUILDINGS GROW TO BE TEENAGERS … USAGE, CONSTANT CHANGE (TEENAGE YEARS)

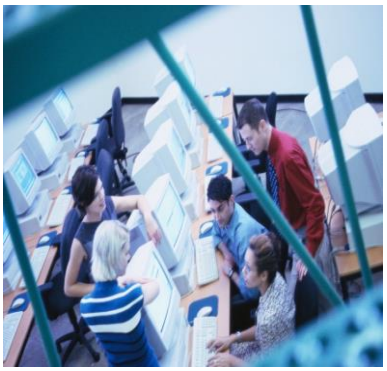
- WEATHER IMPACTS
- STAFF CHANGES
- CHANGES IN INTERNAL LOADS, E.G., COMPUTER, PRINTERS, ETC.
- EQUIPMENT MALFUNCTIONS THAT ARE NOT REPAIRED
- DESIGN FLAWS THAT ARE NOT REPAIRED
- CUBICAL AND WALL RECONFIGURATIONS WITHOUT MOVING DIFFUSERS, THERMOSTATS OR LIGHT SWITCHES
- POOR MAINTENANCE ON EQUIPMENT
  - WORKING DAMPERS, AIR BALANCE
  - CONTROLS
  - CLEAN FILTERS, CLEAN COILS AND REFRIGERANT CHARGE

02 BUILDING PERSONALITY

- Weather impacts from high winds, rain, snow, cold or hot weather.
- Poorly trained personnel that perpetuate problems during the life of the building.
- Changes (moving walls, re-configuring spaces, new HVAC systems, etc.) that are not properly designed, documented or installed perpetuate problems. This challenges maintenance and operations personnel who often resort to an operations philosophy that has most equipment running to satisfy space requirements without really addressing the root cause for problems.
- Due to funding challenges, “band aids” on problems (dampers disconnected, valves held open, equipment placed in 24/7 operation mode, etc.) often is the result. Over time, the current mode of operating the building evolves to become the “Basis of Operation”, even though not remotely close to the “Basis of Design.”
- Buildings that are designed for specific uses, and then used for something totally different, often encounter problems with their HVAC systems when the space use requires higher ventilation rates or greater energy inputs (plug loads, process loads, etc.). When the space loading is reduced, the HVAC systems may be over-sized.
- The control sequences are rarely changed and this results in short-cycling of equipment or staff making changes to air diffusers or thermostats (or adding space heaters/space fans) in response to over-heating or over-cooling problems.
- Operation of poorly designed or poorly understood (complex) systems result in legacy operations handed down to next generation O&M staff. Legacy operations become accepted “optimum” designed operations, without any basis in fact.

AT IS RE-TUNING – UNDERSTANDING BUILDING PERSONALITY PRINCIPLES (CONTINUED)

- BUILDINGS GROW TO BE ADULTS … CURRENT CONDITIONS (ADULTHOOD)
  - HIGH ENERGY COSTS
  - HIGH COMPLAINTS
  - SMALL ZONES DRIVING LARGE SYSTEMS
  - POOR OPERATIONS BASED ON COMPLAINT RESPONSE INSTEAD OF THE BIGGER PICTURE
  - CONTINUANCE OF POOR MAINTENANCE

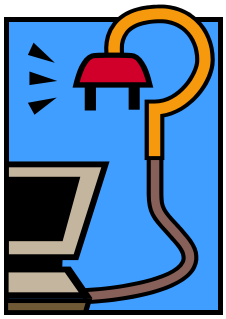


02 BUILDING PERSONALITY

- Economic issues for building owners may result in “run-to-failure” rather than performing proper maintenance, especially in older buildings.
- It is common to find spaces configured for mission uses that they were not designed for. This can result in “tail-wagging-the-dog” operational issues.
- Operation of poorly designed or poorly understood (complex) systems result in legacy operations handed down to next generation O&M staff. Legacy operations become accepted “optimum” design operations, without any basis in fact.
- “Complaint-driven” organizations are reactive in nature. Until they begin to be proactive, they will never “right the ship.”
- Poor maintenance is often a result of how an organization responds to equipment failures (quick fix band-aids) and internal mission-driven priorities.

AT IS RE-TUNING – UNDERSTANDING BUILDING PERSONALITY PRINCIPLES (CONTINUED)

- LIKE CHILDREN, YOU NEED TO GET TO KNOW YOUR BUILDING
- WHEN IS THE BUILDING TRULY OCCUPIED AND HOW IT REACTS TO OCCUPANCY CHANGES
- WHAT IS ITS PERSONALITY
  - HOW DOES IT ACT OR RESPOND TO CHANGING INTERNAL CONDITIONS?
  - HOW DOES IT RESPOND TO WEATHER CHANGES?
  - WHAT IS ITS BALANCE POINT (A POINT WHERE NO HEATING OR COOLING IS REQUIRED TO MAINTAIN COMFORT IN THE BUILDING)?

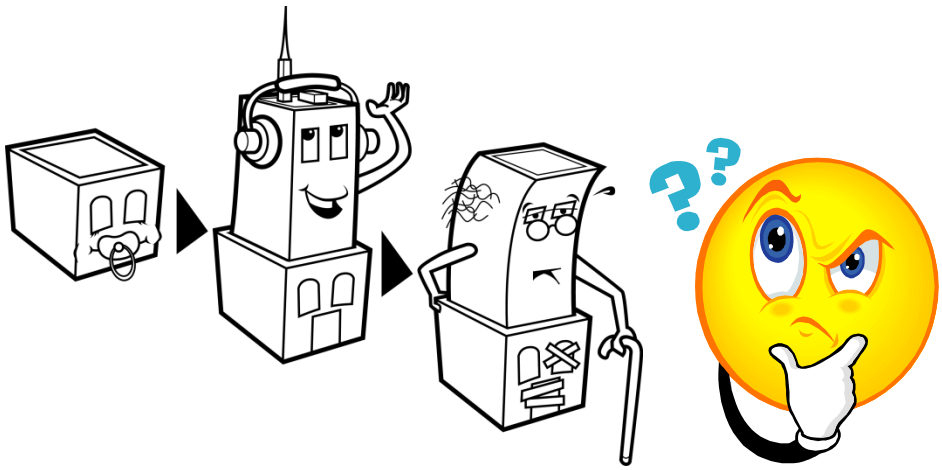


02 BUILDING PERSONALITY

- This can include weather impacts from high winds, rain, snow, cold or hot weather.
- If the building is lightly "occupied" on weekends or at nights, how is it operated (as if fully occupied and loaded, or with minimal HVAC and lighting)?
- Is anyone around at nights or on weekends to observe its "operations", or do we assume?
- What special "process" loads exist in the building (who, what, why and when)?
- How do we determine the "balance" point of the building? Disabling the heating and cooling systems during moderate weather (only use economizer controls to ventilate the building) can help determine the building temperature response and the balance point.

BUILDING PERSONALITY (CONT.)

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

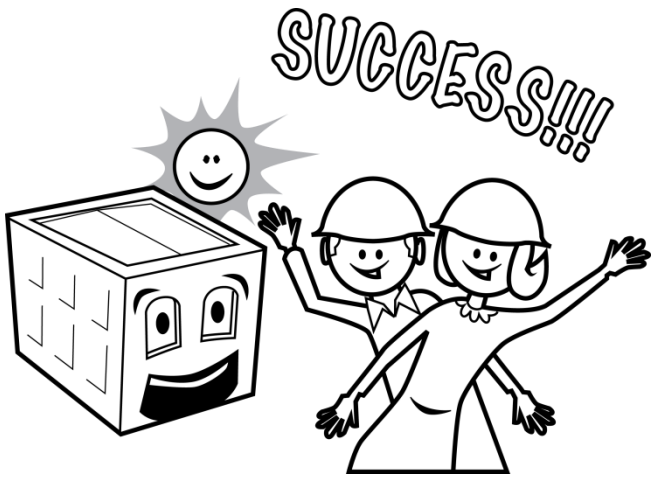


02 BUILDING PERSONALITY

- What is your building's personality?
- How does it respond to changing internal conditions?
- How does it respond to external weather changes?
- What is its balance point, where no heating or cooling is required to maintain comfort?
- This can include weather impacts from high winds, rain, snow, cold or hot weather.
- If the building is lightly "occupied" on weekends or at night, how does it behave?
- Is anyone around at night or on weekends to observe its "response", or do we assume?
- What special "process" loads exist in the building?
- It takes time to actually learn a facility!!

BUILDING PERSONALITY (CONT.)

- A PSYCHOLOGIST WILL ANALYZE A PATIENT TO LEARN A PERSONALITY AND THEN SUGGEST GENTLY BUT PERSISTENT CHANGES IN BEHAVIOR OR ENVIRONMENT TO HELP CHANGE THAT PERSONALITY FOR A MORE ACCEPTABLE RESPONSE TO THE ENVIRONMENT (A HAPPIER PERSON)



02 BUILDING PERSONALITY

- 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 or occupant complaints.

TERMS RELATED TO RE-TUNING

- COMMISSIONING
- RETRO-COMMISSIONING (RCX)
- RE-COMMISSIONING
- CONTINUOUS COMMISSIONING®

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

02 BUILDING PERSONALITY

- Commissioning: Setting up control systems for new construction and major renovations.
- Retro-commissioning: Commissioning for an existing building that has never been commissioned. RCx is a systematic process for identifying less-than-optimal performance in a facility's existing equipment and control systems and making necessary repairs or enhancements to save energy and cost. Whereas retrofitting involves replacing outdated equipment, RCx focuses on improving the efficiency of what is already in place.
- Re-commissioning: Commissioning for a building that has been commissioned before.
- Continuous Commissioning: A continuous practice of commissioning actions for persistent benefits.
- 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 RECENTLY RE-TUNED (3) SMALL COMMERCIAL BUILDINGS WITH UPDATED CONTROLS
- COLLECTED AND ANALYZED INFORMATION
- MADE SMALL, INCREMENTAL CHANGES OVER TIME TO OPTIMIZE PERFORMANCE

02 BUILDING PERSONALITY

- Three 20,000 square foot buildings with almost identical footprints, floor plans and similar city block locations with slightly different orientations and similar HVAC, lighting and envelope designs.
- PNNL staff collected mechanical prints, floor plans, RTU vendor data 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 (via building power metering) before implementing the next change.

MAJOR CHANGES

- RE-COMMISSIONED UNOCCUPIED MODES (TIGHTENED UP SCHEDULES)
- RE-COMMISSIONED STARTUP AND SETBACK SEQUENCES
- INSTALLED WIRELESS TEMPERATURE SENSORS THROUGHOUT THE BUILDINGS
- WIDENED DEAD BANDS ON THERMOSTAT HEATING & COOLING

02 BUILDING PERSONALITY

- Building engineers complained the buildings were consuming too much energy and occupants complained about comfort. This process proved it COULD save energy and reduce complaints simultaneously.
- Reduced night and weekend runtime hours and optimized start times for morning warm up cycles.
- Reset average zone temperature fed into thermostat, based upon wireless sensors to provide a more true reading of multiple offices served by a single zone system.
- This allowed for widening of temperature dead bands and delayed start up times.

CAN IT WORK?

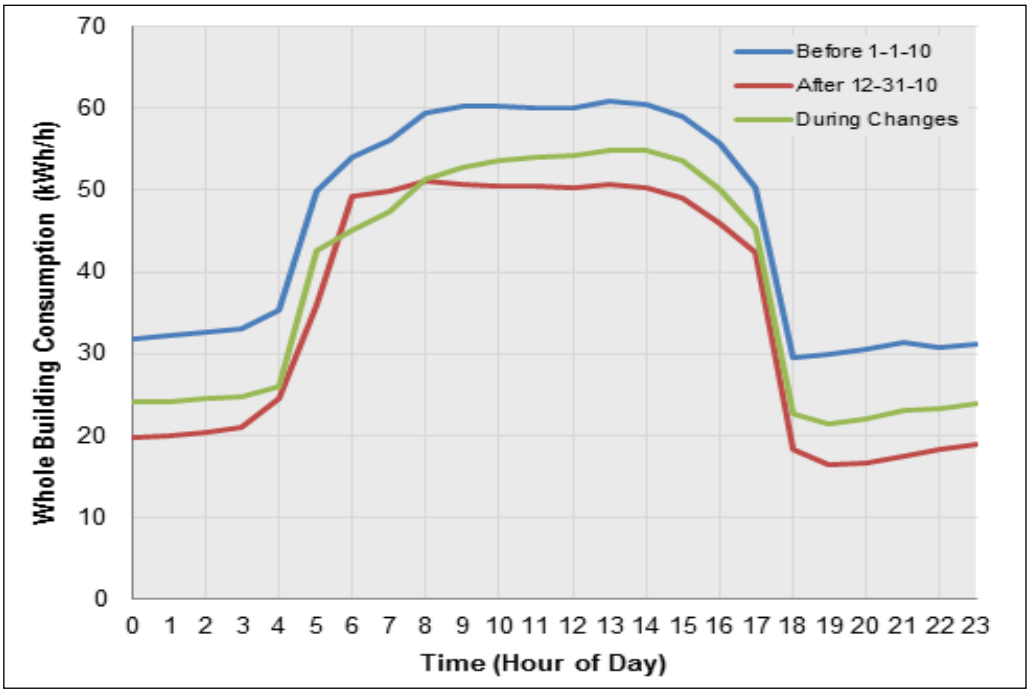


Figure: Weekday Load Profiles for Before, During, and After Re-Tuning Project.

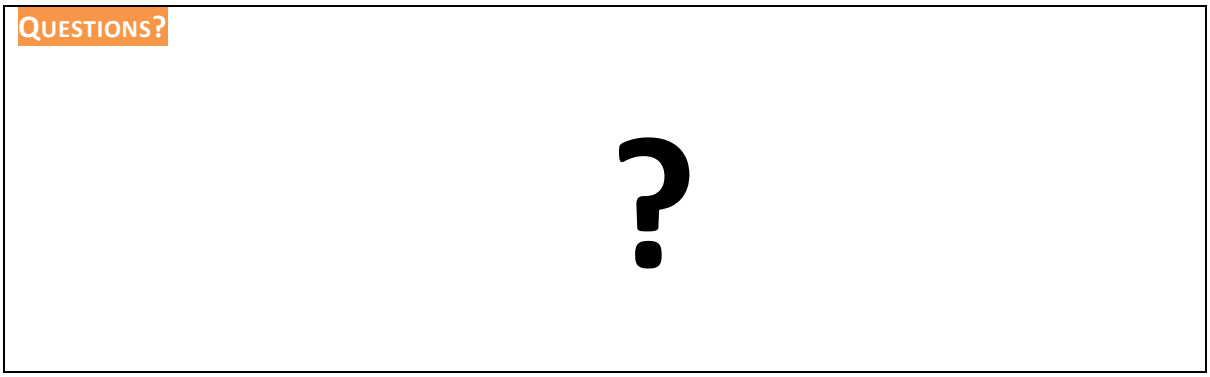
The consumption in the graph is an average for each hour (0-23) over the data collection period (three periods in this case: before, during, and after changes were implemented).

02 BUILDING PERSONALITY

- This data that illustrates that re-tuning works (and takes time).
- The top **blue line** in the graph shows the energy consumption rate for the building before the re-tuning project started.
- The lower **red line** in the graph shows the energy consumption rate for the building after the re-tuning project was completed.

After re-tuning, the facility received an Energy Star rating, energy consumption was down 15 to 20%, and tenant complaints related to comfort were down 50%. Peak savings were realized in shoulder months, which is a typical re-tuning finding.

QUESTIONS?



- Ask the class if they have any questions

Chapter 3: Initial Data Collection Phase – Basic Building Info

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

MATERIALS: POWERPOINT SLIDES 03 INITIAL DATA COLLECTION PHASE

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

03 RE-TUNING STEPS

Four Primary Steps of Small/Medium Building Re-Tuning

- Collect initial building information (data collection = initial phase)
- Building walk-down (Investigation phase)
- Application of prescriptive measures (Implementation phase)
- Reporting of measures implemented and calculated energy savings (Documentation phase)

03 Re-Tuning Steps

- Having an organized data set will be very helpful during the initial phase while gathering basic building information.
- Creating an organized data set (if not already created) will aid the student, building technician and anyone else involved in building re-tuning. Drawings, sequence of operation (SOP) documents, vendor manuals, and re-tuning information gathered over time should all become part of the data set.
- As electronic tools are further developed or utilized, it would not be uncommon to expect pictures, infrared thermal images, portable data logger files (temperatures, power consumption, etc.) and other electronic data to become part of this data set.
- Investigation Phase – this will require the student or building technician to assume nothing. This phase may be the second most difficult – especially for employees who have a long tenure in the building. No one wants to find "improvement" opportunities in their own building, if they are concerned that this will reflect negatively on their past-current performance.
- Implementation Phase – this may be the most difficult phase. Failure to properly implement can result in immediate reversal and conclusion that any further efforts are a waste of time and money. Some no-cost and low-cost changes can be easily implemented without too much concern, but all changes should be carefully reviewed and communicated with all affected building staff (occupants up to management) to ensure everyone is on board.

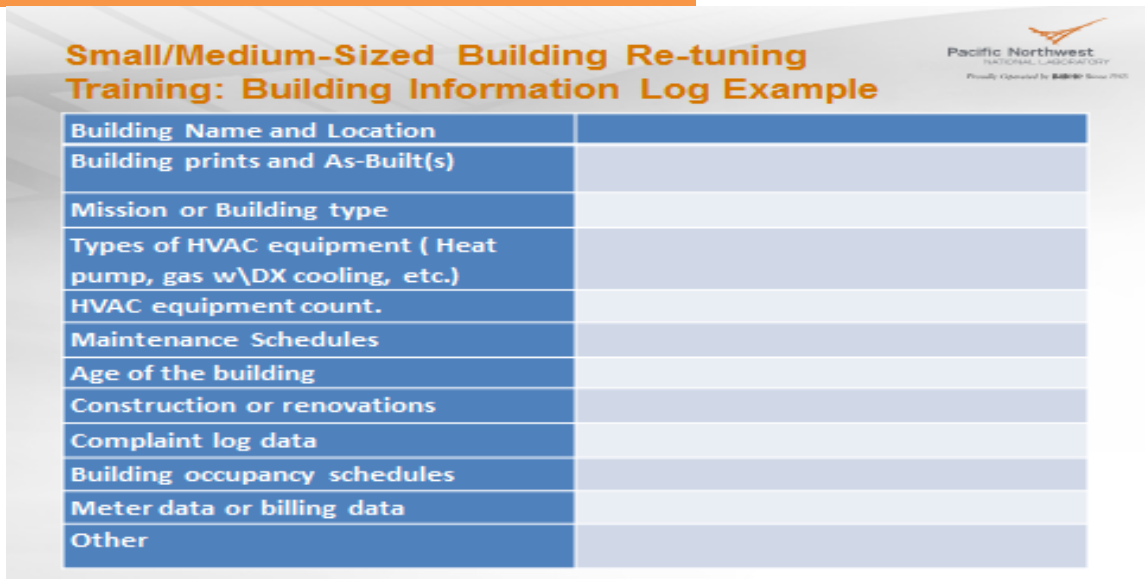
PURPOSE

- DETERMINE THE CHARACTERISTICS OF THE BUILDING AND ITS MECHANICAL SYSTEMS
- GATHER INFORMATION RELATED TO OPERATIONS & MAINTENANCE (O&M) MANUALS, EQUIPMENT REPAIRS, COMPLAINTS, ENERGY PERFORMANCE DATA, OCCUPANCY SCHEDULES FOR HVAC AND LIGHTING SYSTEMS
- SIZE, AGE AND TYPE OF BUILDING, AS-BUILT AND CONSTRUCTION DOCUMENTS, MODIFICATIONS MADE TO THE BUILDING, USE/MISSION CHANGES TO THE BUILDING

03 INITIAL DATA COLLECTION

- The purpose of this step is to determine the overall design of the building and its systems.
- Is the building single floor or multi-floor?
- The age of the building will dictate the code requirements for envelope (windows, wall thickness, and insulation values), HVAC equipment ventilation and efficiency requirements, lighting requirements and other code-mandated design requirements that were in place when the building was designed and constructed. Over time, the only likely improvements would be limited to new HVAC and lighting systems, but this should be documented. Mission changes and equipment failures may have driven changes as well.
- Document all of the information and use a format that is easy to duplicate for multiple buildings (suggest a spreadsheet or simple information log sheet or something similar, sample attached as an appendix to this document).
- This is the first step in the building re-tuning process.
- Information collected will be used in the building walk-down (Investigation phase).
- Information should include the following:
- Size, age and type of building.
- Construction documents (including O&M manuals, Sequence of Operation documents, etc.).
- Equipment repairs, maintenance logs, tenant complaints and changes made in response to failures or needed improvements.
- Building occupancy schedules versus equipment operation schedules.
- Mission/use of the building.
- Metered data (if available).

Building Information to Collect – Log or Spreadsheet



- Building size and geometry, age, mission
- Types of HVAC equipment (Heat Pumps, Split systems, Gas, Hot Water, etc.) and Capacity
- Lighting systems (Time Clocks, Occupancy Sensors, Manual, other)
- Control systems for HVAC and lighting (if any)
- schedules for HVAC and Lighting systems
- Maintenance schedules
- Building repairs or renovations
- Number of occupants, number of zones
- Metered data or billing data

03 Initial Data Collection

- Building geometry: approximate gross square feet, number of floors, general building shape.
- HVAC systems, equipment types and capacity, number of zones.
- Number of major types of equipment, including RTUs, lighting, domestic hot water, exhaust fans, process equipment, etc.
- Did walls go up that split an HVAC zone resulting in ductwork serving an area that is no longer part of the HVAC zone?

- Occupants: Is the building mostly office space? Are there server rooms or floors? Are there any food service spaces (restaurants, cafeteria or coffee shops)?
- Schedules: Occupancy/Lighting/HVAC
- Has the building mission changed (was a warehouse, now converted to office space)?
- Have the HVAC systems serving the building changed or been modified to meet changing missions, poor designs or complaints?
- Are there legacy systems to this building that are no longer needed or used (i.e., smoking rooms with dedicated exhaust fans is common in older buildings)?
- Were renovations done, but not completed (rooftop equipment removed, but ductwork left in place when it should be capped or removed)?
- If you help manage the building, you probably have all or most of this information at your disposal.

QUESTIONS?

03 INITIAL DATA COLLECTION

- Ask if there are any questions.

Chapter 4: Investigation Phase – Building Walk-down

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

MATERIALS: POWERPOINT SLIDES 04 BUILDING WALK-DOWN INVESTIGATION PHASE

LESSON GOAL: KNOW WHAT BUILDING SYSTEMS AND COMPONENTS TO INVESTIGATE

LEARNING OBJECTIVES:

- STATE THE PURPOSE OF PERFORMING A BUILDING WALK DOWN
- LIST THE DIFFERENT SYSTEMS AND COMPONENTS THAT YOU NEED TO FOCUS ON

04 RE-TUNING STEPS

BUILDING WALK-DOWN FOCUS AREAS

- BUILDING ENVELOPE
- HVAC SYSTEMS AND CONTROLS
- LIGHTING SYSTEMS AND CONTROLS
- HOT WATER
- OFFICE EQUIPMENT
- INDOOR ENVIRONMENTAL CONDITIONS
- AIR DISTRIBUTION SYSTEMS (DUCTWORK)
- METER PROFILE

04 INVESTIGATION PHASE

- **Building envelope -** focused on the outside conditions of the building (window and door seals, pipe penetrations, attic insulation, window and door integrity, window shading devices, etc.).
- **HVAC systems** - any and all heating and cooling equipment. This might include any energy saving devices that might be part of the heating and cooling systems (programmable thermostat, variable frequency drives (VFDs), heat recovery systems, time clocks, economizer controls, etc.) and how well they are working. Do the HVAC systems run all the time or only as needed (do schedules match occupancy patterns)?
- **Lighting** – Inside and outside lighting. Include the type of lighting and the light levels found in the inside and on the outside of the building. Include the type of lighting controls (manual or automatic, photocells, etc.) and whether they are working or not. Also review for areas that are over lit and could be de-lamped. Are the lights off at night and on weekends (or whenever the building is not occupied)?
- **Hot water** – any additional hot water heating that might be in the building and what is its function to the mission inside of the building. What is the temperature of the hot water and can it be turned down at night or on weekends?
- **Office Equipment, break room equipment and restaurant equipment** – things that can be turned off or have a sleep mode and equipment having an Energy-Star rating.
- **Indoor Environmental conditions** – focused on the quality of conditions inside of the building and layout of the building. This should include any construction in the building.
- **Air distribution systems** - focused on ductwork, diffusers, roof curbs, etc. used to provide path for airflow into or out of the HVAC equipment.
- **Meter profile** – a valuable tool that, if available, is very helpful when re-tuning and can show the savings when implementing changes in a building.

BUILDING WALK-DOWN FOCUS AREAS GUIDANCE

- USE YOUR SENSES (LOOK, LISTEN, SMELL, TOUCH)
- PERFORM DURING OCCUPIED AND UNOCCUPIED PERIODS
- PERFORM DURING NIGHTS AND WEEKEND PERIODS
- PERFORM DURING THE HEATING SEASON
- PERFORM DURING THE COOLING SEASON
- DOCUMENT, DOCUMENT, DOCUMENT – THE DATA WILL BE USED DURING THE IMPLEMENTATION PHASE

04 INVESTIGATION PHASE

- Has the building mission changed (was a warehouse, now converted to office space)?
- Have the HVAC systems serving the building changed or been modified to meet the changing mission?
- Construction or renovations are considered “post” initial building construction activities.
- Are there legacy systems in this building that are no longer needed or used (smoking rooms with dedicated exhaust fans is common in older buildings)?
- Were renovations done, but not completed (rooftop equipment removed, but ductwork left in place when it could be capped or removed)?
- Did walls go up that split an HVAC zone resulting in a ductwork serving an area that is no longer part of the HVAC zone (thermostat in the wrong location or two HVAC zones serving the same area – possibly fighting each other)?
- Have manual light switches been removed or located in the wrong location (occupants have no control over office lighting)?
- Are certain areas over lit?
- Rotating equipment (fans, motors, pumps) making unusually loud noises?
- Are the lights off at night or when the building is not occupied?
- Are HVAC systems (fans, pumps, chillers, boilers) off at night or when not needed (or are they active – just in case)?
- Suggest creating a log sheet (example logs attached in appendix).

BUILDING WALK-DOWN TOOLS (TOOL KIT)

04 INVESTIGATION PHASE

- **Building envelope –** Camera, thermal imaging camera and Infrared (IR) temperature gun.
- **HVAC systems** – Tape measure, air flow velocity sensor, IR temperature gun, camera, thermal imaging camera, wet-bulb sensor, screwdriver, wrench.
- **Lighting** – Light meter, electronic ballast detector (flicker).
- **Hot water** – Camera, thermal imaging camera and IR temperature gun.
- **Office Equipment, break room and food-related equipment** – camera, IR temperature gun.
- **Indoor Environmental conditions** – camera, IR temperature gun, tape measure.
- Low cost tools shown include temperature gun (Infrared), Light Level Meter (foot candle or lux or both), digital camera, tape measure, tools for opening roof top panels, etc.
- Higher cost tools might include a thermal imaging camera (shown), CO_2 monitor (not shown), digital manometer (not shown), airflow hood (not shown), etc.

QUESTIONS?

?

04 INVESTIGATION PHASE

- Ask if there are any questions.

Chapter 5: Investigation Phase – Building Envelope

INSTRUCTOR GUIDANCE

TIME: 60 MINUTES

LESSON GOAL: LEARN HOW TO WALK DOWN THE OUTSIDE OF THE BUILDING

MATERIALS: POWERPOINT SLIDES 05 BUILDING ENVELOPE INVESTIGATION PHASE

LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN REVIEWING DOORS AND WINDOWS
- WHAT TO FOCUS ON WHEN REVIEWING WALLS AND ROOFS

05 RE-TUNING STEPS

BUILDING ENVELOPE WALK-DOWN: DOORS AND WINDOWS

SEALS WEAR OUT AT THE BOTTOM OF DOORS FIRST.

05 INVESTIGATION PHASE – BUILDING ENVELOPE

Doors – prescriptive checks:

- Check door seals along the bottom edges.

BUILDING ENVELOPE WALK-DOWN: DOORS AND WINDOWS

SEALS WEAR OUT ALONG THE VERTICAL EDGES LAST, OR ARE NOT EVEN INSTALLED.

05 INVESTIGATION PHASE – BUILDING ENVELOPE

Doors – prescriptive checks:

- Check door seals along the side edges.
- A tight seal or lack of a tight seal can influence the indoor environment.

BUILDING ENVELOPE WALK-DOWN: DOORS AND WINDOWS

LOADING DOCKS OFTEN HAVE DOORS THAT LEAD TO THE BUILDING INTERIOR

Doors – prescriptive checks:

- When a building has a loading dock or freight delivery area, the interior doors of that loading dock become “exterior” doors by virtue of the freight being delivered for extended periods of time.
- These interior doors, that become exterior doors, need to have their seals inspected or installed if missing (as shown in this picture).
- Light coming from under a door or through the side gap is a tattle-tale indicator of missing seals.

BUILDING ENVELOPE WALK-DOWN: DOORS AND WINDOWS

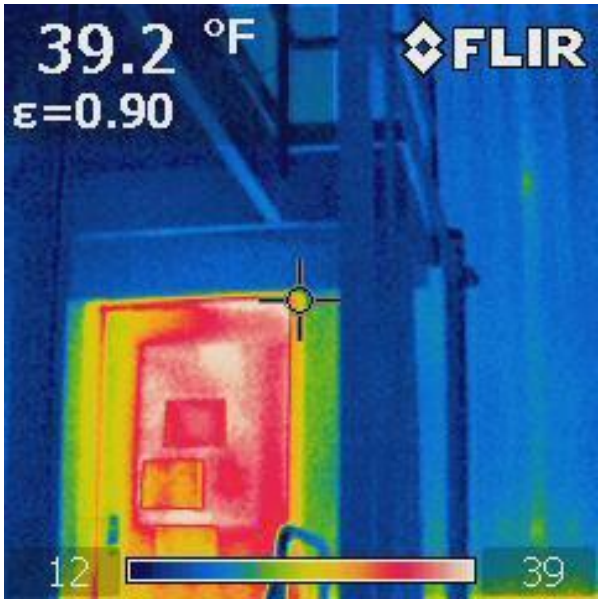
CRACKED GLASS CAN BE A HAZARD AS WELL AS AN ENERGY LOSS

05 INVESTIGATION PHASE – BUILDING ENVELOPE

Windows – prescriptive checks:

- Check for cracked window panes.
- Check for cracked, chipped or missing window glazing or caulking.

BUILDING ENVELOPE WALK-DOWN: DOORS AND WINDOWS



- UN-INSULATED OR POORLY INSULATED DOORS CAN CONTRIBUTE TO HIGHER HEATING AND COOLING COSTS

05 INVESTIGATION PHASE – BUILDING ENVELOPE

Exterior Doors – prescriptive checks:

- Check for thermal images of poorly insulated exterior doors that may need to be replaced.
- Check for interior heating or cooling systems that are located just inside the door. If they are running for significant amounts of time, this could be indicative of a poorly insulated door or a door with poor seals that need to be repaired or replaced.
- It is not uncommon to find dedicated wall heaters (electric or hot water) located just inside exterior doors like these. Most of the heat from these heaters simply conducts through the door to the outside.
- Many solid-core doors with high insulation properties, fire ratings and other features (windows, hardware, etc.) now exist on the market. If unsure of the correct door replacement, consult with a professional.

BUILDING ENVELOPE WALK-DOWN: AWNINGS AND WINDOW SHADES

- USE SUN SHADES, BLINDS OR SIMILAR WINDOW TREATMENTS TO REDUCE SOLAR GAIN AND GLARE

05 INVESTIGATION PHASE – BUILDING ENVELOPE

Window shading devices – prescriptive checks:

- Check for installation of awnings or window treatments.
- Check that they are closed to block solar glare and gain and open to receive natural light.
- Seasonal changes may mandate they be open during cold weather (to admit solar gain and natural lighting).

BUILDING ENVELOPE WALK-DOWN: INTERIOR WINDOW SHADING DEVICES

- USE BLINDS TO REDUCE SOLAR GAIN AND GLARE

05 INVESTIGATION PHASE – BUILDING ENVELOPE

Window shading devices – prescriptive checks:

- Check for installation of window treatments.
- Check that they are closed to block solar glare and gain and open to receive natural light.
- The building on the right was able to reduce solar gains through many activities, including aggressive use of window treatments on the southern exposures. This allowed the building to keep the chilled water system off until outdoor-air temperatures were almost 70°F.

BUILDING ENVELOPE WALK-DOWN: ROOFS

- CLEAN ROOF AND NO DEBRIS?

05 INVESTIGATION PHASE – BUILDING ENVELOPE

Roofs – prescriptive checks:

- Check for a clean roof.
- Check that no debris is accumulated which could block roof drains or deteriorate the roof's reflective capabilities.
- Sunglasses and sunscreen may be needed on adequately maintained white roofs (the glare could be blinding)!

BUILDING ENVELOPE WALK-DOWN: ROOFS

- CLEAN ROOF AND NO DEBRIS?

05 INVESTIGATION PHASE – BUILDING ENVELOPE

Roofs – prescriptive checks:

- Check for a clean roof.
- Check that no debris is accumulated which could block roof drains or deteriorate the roof reflective capabilities.
- Sun glasses and sun screen may be needed on adequately maintained white roofs (the glare could be blinding)!
- Air-cooled equipment (as shown) may see temperatures significantly higher on dark roofs when compared to white roofs. Darker roofs may affect equipment cooling performance and possibly occupant comfort issues.

BUILDING EXTERIOR LOUVERS AND GRILLS: POSSIBLE BLOCKAGE OR SHORT-CIRCUITING

POSSIBLE BLOCKAGE FROM BUSHES OR OTHER PLANTS?

Exterior louvers and grills – prescriptive checks:

- Check that trees, bushes and plants are not clogging or blocking intake louvers.
- Check that intake and exhaust louvers are not in close proximity to each other, resulting in possible short-circuiting of unwanted exhaust air from the building (as shown above).
- In this case, the building design created this potential problem (exhaust air being re-entrained into the outdoor-air intake), which might impact economizer operations.
- During the building walk-down, it is important to note design issues, which may be impacting energy, equipment efficiency or occupant comfort and indoor-air quality (IAQ) issues.
- These issues can be brought to the attention of the building owner/building manager for further review and prioritization of capital improvements.

Building Envelope Walk-down: Doors and Windows

- Focus on outside conditions of the building
- Door and window types
- Holes in the building
- Other

05 Investigation Phase – Building Envelope

Windows and doors – prescriptive checks:

1. Seals around the doors and windows.
2. Shades in the windows, and are they used (consider seasonal effects)?
    A. A valuable way to help minimize the HVAC load – reduce cooling in summer, but then raise shades to provide daylight in the winter.
3. Look at roll-up doors also and check the roll-up door seals.
4. Look for cracks in the caulking around the windows and doors and seismic joints (or missing caulking).
5. Are the windows and doors double pane or single pane?
6. Are the windows and doors open? This could signal a problem related to heating and cooling or ventilation. It can also be a security issue when the building is not occupied.

Holes in the building – prescriptive checks:

1. Look for holes around seams (or seismic joints) in the building and around anything that enters the building (pipe penetrations). Holes will allow for additional infiltration into the building, which will add additional load to the heating and cooling equipment. Have there been any problems or indication of vermin (mice or rats) entering the building?

2. Don't forget to check roofs and roof curbs for related issues.

Insulation issues – prescriptive checks:

1. Use a temperature gun or thermal imaging camera and take temperature readings of the walls and the ceiling. This will give you an idea of the insulation in the walls or lack thereof. There should be a significant temperature difference between the outdoor and indoor temperatures during summer and winter months.

2. Attics without adequate insulation should be reviewed.

3. Look for missing insulation on any piping that carries heated water, chilled water or steam. Missing insulation will contribute to energy costs and is a low-cost fix.

Ventilation issues – prescriptive checks:

1. May not be an energy item, but can contribute to a stuffy building or a building with unusual odors.

2. This can be a factor in a sick building.

Roof and HVAC grilles & louvers – prescriptive checks:

1. In some building there may be wall-mounted louvers and grills for the heating and cooling systems and exhaust systems. These louvers and grills need to be clean and free of debris. If trees, shrubs or bushes are in close proximity to these grills and louvers, ensure that they are trimmed to be far away from the grills – especially on intakes.

2. Roof top units have intake screens at the outdoor-air damper location. These need to be periodically inspected and cleaned when they get dirty.

3. White membrane roofs need to be clean. When clean, a white roof has its best solar reflective properties. There can be as much as 3 degrees of improvement in heat rejection for a clean roof compared to a dirty roof.

Heat trace – prescriptive checks:

1. Should be turned off in the summer. Heat trace is generally found on water lines into the building and on rain gutters or storm drains on the building.

2. The heat trace may come with temperature controls (outdoor-air temperature set point). Ensure the set point is no higher than 40^{o}F. Some controls are temperature and liquid/ice based. Ensure they are working properly.

3. A touch and feel method for determining if the heat trace is on (when it should not be), is the quickest for this recommendation (be careful not to burn yourself)!

BUILDING ENVELOPE WALK-DOWN: WINDOW CHECKS

- FOCUS ON OUTSIDE CONDITIONS OF THE BUILDING
- OUTSIDE WINDOWS
- WINDOWS SHOULD BE CLOSED IF OPERABLE
- WINDOWS SHOULD HAVE NO OBSERVABLE CRACKS OR DAMAGE TO THE FRAMES AND THE SEALS (OR GLAZING IF OLDER WINDOW)

05 INVESTIGATION PHASE – BUILDING ENVELOPE

Windows – prescriptive checks:

- The number refers to how many layers of glass each window has. The more layers of glass, the better insulated the window and the more it costs. In between each layer is an insulating gas. Double pane windows are about three times as well insulated as single pane windows, and triple pane windows are about four times as well insulated.
- Typical cost savings for heating and cooling, when choosing ENERGY STAR rated windows, is estimated to be $146 (California) -$501 (New England) per year when replacing single-pane windows. Cost savings vary from region to region across the U.S. (http://www.energystar.gov/index.cfm?c=windows_doors.pr_benefits).
- Because windows are one of the least insulated parts of a building, double panes are usually considered the standard for a well-insulated building.
- Moisture inside the panes indicates a failed window (frame or seal) and may or may not be able to be repaired (replacement is the other option if repair cannot occur).
- If the building has several windows, suggest spot checking.
- Estimate the window-wall ratio (WWR). This is the window area compared to the wall area. The higher the ratio, the greater the impact on the building from outside ambient conditions and greater solar gain impacts – both of which can impact HVAC sizing and performance issues.

BUILDING ENVELOPE WALK-DOWN: WINDOW DISCUSSION

- Because windows are one of the most poorly insulated parts of a building, double panes are usually considered the standard for a well-insulated building.
- You can tell how many panes a window has by looking at where it connects with the frame. If there are no dividers, its single pane, if there is one divider, its double pane, and if there are two dividers, its triple pane.
- If there is condensation between the window panes, it usually means the integrity of the seal between the panes has been compromised (which usually means the insulating properties are also diminished).

Building Envelope Walk-down: Door and Windows

- Check seals around doors and windows
- Are seals missing on doors
- Cracks in caulking or glazing for windows
- missing caulking or glazing for windows
- Moisture between window panes or cracks in window panes

05 Investigation Phase – Building Envelope

Windows and Doors – prescriptive checks

- Check to see if seals around the doors and windows are in place and in good condition.
- Check to see if door sweeps are in place and in good condition.
- Look at roll-up doors and check the roll-up door seals.
- Check to see if cracks in the caulking exist around the windows and doors.
- Check to see if the windows and doors are double pane or single pane (if single pane, should they be replaced).
- Check to see if operable windows and doors are open? This could signal a problem related to heating and cooling or ventilation (and could also be a security/theft issue and provide access to wildlife).
- Check to see if any window panes are cracked (for double-pane windows, this means the insulation value is lost).
- Check to see if any double-pane windows are showing signs of broken seals between the panes (moisture between panes).
- Check for cracks in caulking/glazing around windows and doors and seismic joints.

Building Envelope Walk-down: Windows and Door Shades

- Operable shades should be used correctly
- Replace or add shades to windows that are missing them
- Is the goal for day lighting or for managing solar gain (or both)?

05 Investigation Phase – Building Envelope

Windows and Door Shades – prescriptive checks

- Are shade devices located in the windows? Check to see if they are used? Consider seasonal effects.
- Shades are a valuable way to help minimize the HVAC load – reduce cooling in summer.
- Check to see if shades are open to provide daylight in the winter and increase solar gain (northern/cold climate zones). This assumes that lights are automatically or manually kept off when not needed.
- During summer peak cooling loads, operable shades are a significant means to reduce solar heat gain. Check to see if occupants leave their window shades open, are they turning their lights off (natural daylight)? If not, the facility may encounter additional costs for cooling via solar heat gain and for lighting with lamps and ballast.
- Check to see if the windows are double pane or single pane?
- Check to see if the operable windows and doors are open? This could signal a problem related to heating, cooling or ventilation (and could also be a security/theft issue).

BUILDING ENVELOPE WALK-DOWN: UNSEALED PENETRATIONS IN THE ENVELOPE

- BUILDING SEISMIC JOINTS, PIPING PENETRATIONS, LEGACY HOLES
- INDICATIONS OF INFILTRATION OF OUTSIDE AIR, DUST?
- INDICATIONS OF VERMIN ENTERING THE BUILDING?

Holes in the Building – prescriptive checks

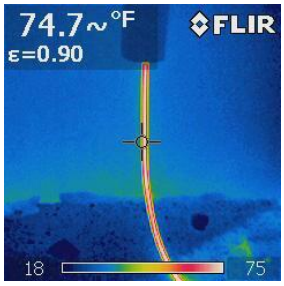
- Look for holes around seams in the building and around anything that enters the building (pipe penetrations). Holes will allow for additional infiltration into the building, which will add additional load to the heating and cooling equipment. Have there been any problems or indication of vermin (mice or rats) entering the building? Cafeterias or sources of food that are being contaminated should be evaluated with this in mind. What about unwanted insects?

Typical pipe penetrations that one should review or might encounter include the following:

- Fire sprinkler piping, natural gas piping, electrical conduits, water lines and abandoned piping – check for gaps, missing caulking, etc.
- Outlets and other electrical fixtures on the outside of the building – check for missing seals, etc.
- New security cameras and related equipment – check for missing weather seals and/or caulking.
- Un-heated parking garages under buildings or buildings with overhangs – the occupied spaces directly above may be encountering “envelope” related challenges and should be checked for missing insulation or poor insulation.
- Frozen water lines inside a building are often an indicator of a compromised envelope, negative building pressurization condition or both.

BUILDING ENVELOPE WALK-DOWN: HEAT TRACE AND OTHER PLUG LOADS

- GUTTERS AND EXPOSED PIPING WITH HEAT TRACE CONFIGURED PROPERLY?

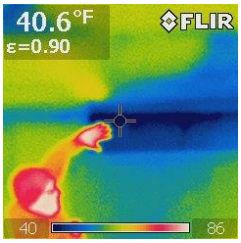


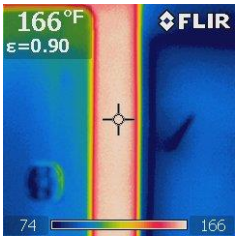
05 INVESTIGATION PHASE – BUILDING ENVELOPE

Heat Trace – prescriptive checks

- Heat trace is generally found on water lines into the building and on gutters or storm drains on the building and should be turned off in the summer (automatically or via seasonal PM)
- The heat trace may come with temperature controls (outdoor-air temperature set point). Ensure the set point is no higher than 40°F. Some controls are temperature and liquid/ice based. Ensure they are working properly.
- A touch and feel method for determining if the heat trace is on (when it should not be) is the quickest for this recommendation (be careful!) or use an infrared camera to validate during warmer weather.
- These can be overlooked plug loads that could be better managed.
- Check for heat trace on when not needed (this image is on a 40°F day and the heat trace serves a downspout for a rain gutter system)
- Heat trace can be on, even in the summer, and easily overlooked.
- Check for other plug loads on the exterior of the building that might be legacy or left over from other activities (lighting, construction, etc.).

Building Envelope Walk-down: Insulation Checks





- Building structure insulating integrity?
- Walls, doors, ceilings?
- Piping insulation on domestic hot water, heating water, steam or chilled water lines?
- Piping insulation on DX cooling system lines?

05 Investigation Phase – Building Envelope

Insulation – prescriptive check

Use a temperature gun or thermal imaging camera and take temperature readings of the walls, ceilings and exterior doors. This will give you an idea of the insulation integrity of the structures. You need to have a good temperature difference between the outdoor and indoor temperature for a good thermal analysis.

- Check for missing insulation on any piping that carries heated water, chilled water, steam condensate or steam. Missing insulation will contribute to energy costs and is a low-cost fix.
- Check for un-heated parking garages under buildings or buildings with overhangs – the occupied spaces directly above these spaces should be checked.
- Check hot water, chilled water, steam, and condensate lines for missing insulation.
- Often, construction or maintenance related activities (or both) result in the removal of insulation from piping and wall/attic spaces. In many instances, it is not uncommon to find that insulation that was removed was never replaced.
- Asbestos containing material (ACM) is commonly found in older buildings or older insulating systems. If the building is suspected of having ACM in the piping or other building insulation systems, it is recommended that students be instructed to have their responsible safety organization inspect and approve any activity prior to disturbing areas with possible ACM.
- Check roll-up and exterior doors for missing or poor insulating properties. Exterior doors are often sources of significant heat gain/losses in a building's envelope. Replacing doors might be a low-cost effort. If the door needs to be replaced because of age or failure, the added cost for an insulated door should be considered over pursuing a "like-kind" replacement.

BUILDING ENVELOPE WALK-DOWN: ROOFS

- IS THE ROOF WHITE?
- IS THE ROOF CLEAN OF DEBRIS?
- A WHITE MEMBRANE ROOF NEEDS TO BE CLEAN TO HAVE THE BEST PERFORMANCE

Roof – prescriptive checks

- Check that the roof is clean. White membrane roof needs to be clean to be most efficient. There can be as much as 3 degrees of improvement in heat rejection versus a dirty roof.
- Check attics for adequate insulation.
- Check that debris is removed from the roof periodically. Rain and snow may not drain properly if roof drains are clogged with leaves or needles and dirt. This can result in water finding a path into the roof causing further damage to the roofing materials (mold, reduced insulation properties, etc.).

BUILDING ENVELOPE WALK-DOWN: ATTIC AND CRAWL SPACES

- IS THE ATTIC OR CRAWL SPACE PROPERLY VENTILATED?
- IS INSULATION MISSING OR DAMAGED?
- ARE THERE LEGACY EXHAUST VENTS OR FAN SYSTEMS THAT NEED TO BE REMOVED OR CAPPED?

Attic and crawl spaces – prescriptive checks

- Check for attics without adequate insulation.
- Check for insulation that has dropped or fallen out of place in attics (this is a common problem).
- Check for louvers and grills for the attic and/or crawl spaces. These louvers and grills need to be clean and free of debris. They should have trees and bushes trimmed away from the louvers and grills.
- Check for attic spaces with powered exhaust fans. They should be verified to activate from a thermostat control (generally set to activate when the attic space temperature is > 100°F). If backdraft dampers are part of the exhaust fan design, they should be verified (closed when the exhaust fan is off, open when the exhaust fan is on).
- Check that crawl spaces (generally in cold climate zones) with vents are sealed to prevent excessively cold air from infiltrating under the building, where water lines, ductwork or other un-insulated systems may be located. Check with your local utility provider to see if this is a recommended activity for your climate zone, in the winter or as part of pre-winterization actions. In the spring, these vents should be opened back up.
- Attics and crawl spaces are rarely visited due to their location and “hazards”, so they often are “hiding” problems.
- Attics can be very hot in the summer and may require protection (dust mask, etc.).
- Crawl spaces may also have similar concerns due to insects or small rodents.
- Abandoned or disconnected equipment (exhaust fans, ductwork) and failed insulation (insulation which has fallen from roof or floor joist spaces, etc.) is not uncommon to find in these spaces.

QUESTIONS?

05 INVESTIGATION PHASE – BUILDING ENVELOPE

- Ask if there are any questions.

Chapter 6: Investigation Phase: HVAC Systems and Controls

INSTRUCTOR GUIDANCE

TIME: 60 MINUTES

LESSON GOAL: LEARN HOW TO WALK DOWN THE HVAC SYSTEMS OF A BUILDING

MATERIALS: POWERPOINT SLIDES 06 HVAC SYSTEMS AND CONTROLS INVESTIGATION PHASE

LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN REVIEWING PACKAGED EQUIPMENT (ROOFTOP UNITS ETC.)
- WHAT TO FOCUS ON WHEN REVIEWING THERMOSTAT CONTROLS
- USING THE SENSES (VISUAL, AUDIO, FEEL, SMELL) TO DETECT PROBLEMS

06 RE-TUNING STEPS

BUILDING WALK-DOWN – HVAC SYSTEMS AND CONTROLS

- SMALL/MEDIUM-SIZED BUILDINGS TYPICALLY HAVE PACKAGED AIR-CONDITIONERS WITH GAS FURNACES OR HEAT PUMPS WITH EITHER A GAS FURNACE OR AUXILIARY ELECTRIC STRIP HEATING
- MANY OF THESE UNITS ARE NOT PROPERLY MAINTAINED
- PACKAGED UNITS ARE TYPICALLY CONTROLLED BY WALL MOUNTED THERMOSTATS WITH VARYING FUNCTIONALITY
- SMALL/MEDIUM-SIZED BUILDINGS TYPICALLY HAVE PACKAGED AIR CONDITIONERS WITH GAS FURNACES OR HEAT PUMPS WITH EITHER GAS FURNACE OR AUXILIARY ELECTRIC STRIP HEATING

06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

Gas-Fired Equipment – prescriptive checks

- Verify that the combustion-air intake is properly configured with no blockages.
- Verify that the gas pressure regulator is set correctly.

BUILDING WALK-DOWN – HVAC SYSTEMS: INSPECTIONS

- COUNT THE NUMBER AND TYPE OF HVAC UNITS AND CAPACITY RATINGS
- SPLIT OR PACKAGED UNITS?
- AIR CONDITIONERS WITH GAS HEAT OR HEAT PUMPS WITH ELECTRIC HEAT?
- MISSING COMPONENTS? DOOR PANELS MISSING?
- LEVEL OF MAINTENANCE?

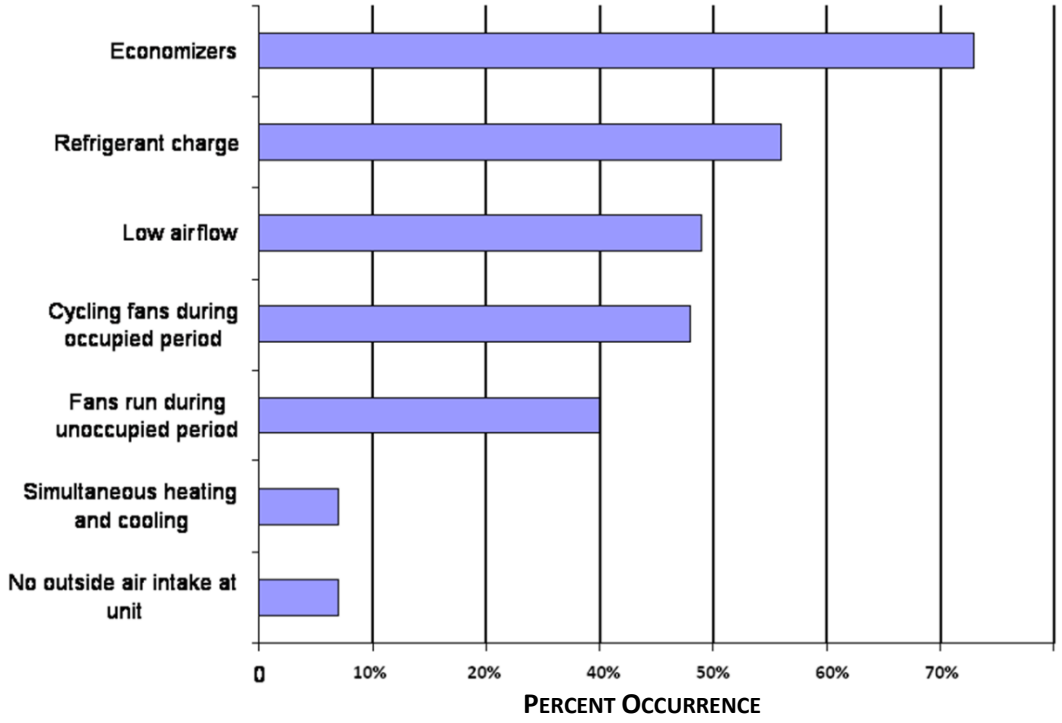
06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – prescriptive checks

- While counting the HVAC system units, check how many serve the perimeter spaces of the building and how many serve the interior spaces. Later, when asking the occupants for indications of complaints, their location (perimeter or interior space) will be relevant to the units noted.
- Check split systems that have the condenser coil (outdoor unit) remotely located from the indoor fan and evaporator section. The outdoor unit will either be on the roof or located at ground level. Ensure all coils are clean, the piping is secure and the outdoor fan is working correctly.
- Check to see if the gas isolation valve is turned on for gas-fired heating systems.
- If there is an outside thermostat that locks out the gas or auxiliary electric heating, check to see what temperature it is set at? It should be set at the vendor's recommended set point to allow the compressor heat to be used for maximum energy efficiency.
- Check to see if the economizer dampers are set at their minimum position when not economizing. Calculate the outdoor-air fraction (OAF) by taking (3) temperature readings to validate that the minimum damper position control is working properly. This includes the return-air temperature (RAT), mixed-air temperature (RAT) and outdoor-air temperature (OAT).
- The equation for this is as follows: [(RAT-MAT) / (RAT-OAT)] * 100. For example, if the temperatures recorded are: RAT = 72, MAT = 60 and OAT = 40, the equation would be [(72-60) / (72-40)] * 100 = [12/32] * 100 = 37.5% open. Normally, minimum damper settings would not be more than 10% to 20% open. This might indicate the HVAC unit is over-ventilating when the damper is at its minimum setting and is in need of some adjustment.

- Check for missing components including condenser fans, belts, panel doors, dampers, actuators, etc.
- Poor maintenance can be indicated by signs of oil on refrigerant piping connections at coils and compressors (indicating refrigerant leakage), loud humming or vibration from rotating equipment and other equipment degradation visual and audible indicators.

BUILDING WALK-DOWN – HVAC SYSTEMS: TYPICAL PROBLEMS



- ECONOMIZER PROBLEMS > 70% OF THE TIME

06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – prescriptive checks

A New Buildings Institute (PIER) project identified a number of problems with HVAC systems as they are installed and operated in the field.

- Checks for problems should include looking for broken economizers, improper refrigerant charge, fans running during unoccupied periods, fans cycling on and off with a call for heating and cooling rather than providing continuous ventilation air during occupied periods, low air flow, inadequate ventilation air, and simultaneous heating and cooling.
- If low air flow is observed, check for dirty filters, dirty intake screens, dirty coils, slipping belts, weak motors, or other mechanical problems.
- Checks for design problems should also be observed and noted. Design problems can include under-sized ductwork, under-sized capacity, installed equipment without access doors for maintenance or poorly located access doors. It can also include walls that have been moved, resulting in improper airflow or zoning issues.

BUILDING WALK-DOWN – HVAC SYSTEMS INSPECTIONS: USING THE SENSES FOR INSPECTIONS

- LOOKING FOR PROBLEMS – VISUALLY INSPECTING ALL PARTS OF THE UNIT IS ONE WAY TO FIND PROBLEMS WITH THE UNIT DURING MAINTENANCE
- FEELING FOR PROBLEMS – FEELING FOR AIR LEAKS IS ANOTHER WAY TO FIND PROBLEMS WITH A UNIT DURING MAINTENANCE
- LISTENING FOR PROBLEMS – LISTEN FOR UNUSUAL NOISES LIKE THUMPS OR BANGING, COULD BE SIGNS OF A PROBLEM WITH A FAN OR OTHER ROTATING MECHANICAL AND ELECTRICAL COMPONENTS
- SMELLING FOR PROBLEMS – IF A WIRE OR COMPONENT BURNS OUT THERE USUALLY IS A BURNT SMELL IN THE COMPARTMENT OF THE UNIT, OR AN OCCUPANT OF THE BUILDING WILL LET YOU KNOW THAT THEY SMELLED A BURNING SMELL IN THE VENTS
- USE OF OUR SENSES AS A TOOL FOR TROUBLESHOOTING CAN HELP DISCOVER PROBLEMS
- MOST PROBLEMS FOUND (OR PREVENTED) DURING MAINTENANCE ARE DISCOVERED VISUALLY

06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – prescriptive checks

- Look (most problems found with good visual inspection)
- Feel
- Listen
- Smell

BUILDING WALK-DOWN – HVAC SYSTEMS: VISUAL INSPECTIONS

- WHAT ARE WE LOOKING FOR?
- MISSING COMPONENTS?
- DAMAGED COMPONENTS?

06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

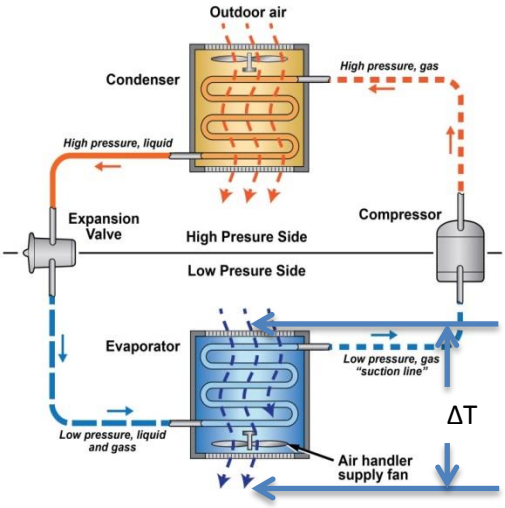
HVAC Systems – prescriptive checks

- When you see a bunch of sheet metal screws lying on the roof or near the HVAC system, this usually indicates that the last maintenance effort that removed the screws did not replace them. Make sure enough screws are adequately installed to keep panels securely in place.
- Check for components that are lying on the roof or ground that are indicative of failed equipment (broken belts, busted fans, failed motors, etc.). This may be an indication that the unit is not operating, not operating at full capacity, or as designed.
- Check for damaged indoor or outdoor coils.
- Check for missing or damaged mechanical items (fan motors, blades, belts, etc.).
- Check for signs of belt debris (under belt guard/pulley/sheave) and belt wear/slippage.
- Some roof top units have built-in exhaust (relief) fans. When they operate, they should blow open a gravity weighted louver which should close when the exhaust/relief fan is not running. If this louver does not fully close, it may allow cold or hot air to infiltrate into the supply fan intake via the return damper. This will cause the mixed air sensor to read colder in the winter and warmer in the summer, but ultimately result in higher energy costs to temper the airstream.

Building Walk-down– HVAC Systems: Visual Inspection of Coil Section

- Visual inspection
- Are the indoor/outdoor coils and fins dirty?
- Is the coil damaged or leaking?
- Is the drain pan and drain line clean and clear of debris?
- In cooling mode, measure the temperature difference across the evaporator coil when the compressor is on; it should be 18 to 22°F for a single compressor unit or multi-compressor unit that is fully loaded.

Source: http://www.amistee.com/commercial-coil-cleaning-mi.htm



HVAC Systems – prescriptive checks

- Follow vendor recommendations for cleaning agent(s) and application for indoor evaporator coil and outside condenser coil cleaning. Wear appropriate personal protective equipment (PPE) for eye and skin protection. Also beware of any fumes that could be generated, and ventilation requirements.
- Be careful to not damage coil fins when spraying down with water solution and always be sure water is draining out the drain pan and connecting P-trap (previously discussed), otherwise water may back up or find its way into the building, possibly causing water damage, etc.
- A dirty filter and/or dirty coil can cause the evaporator coil to freeze, and this can lead to compressor damage (flood back of liquid). Clean coils and filters are critical to safe, efficient equipment operation.

- Coils should be rinsed with a spray application in the opposite direction of normal airflow. For the typical “A-frame” coil (picture shown), this is determined by the fan location and discharge direction (up flow or down flow).
- Drain pans should be checked to ensure they are not clogged with debris and water is able to flow freely. Traps should be primed with water and installed correctly. Drain lines should be pitched correctly.
- **NOTE: take precaution and care when cleaning with caustic or strong cleaning agents (skin/burn issues).**

Building Walk-down – HVAC Systems: Visual, Audible and Sensory Inspections (Cont.)

- What are we looking for?
- What are we listening for?
- Coil conditions?
- Air leaks?
- Oil leaks?

06 Investigation Phase – Building walk-down HVAC Systems

HVAC Systems – prescriptive checks

- Check for deteriorating condensing coil conditions from corrosive air (salt water, etc.). Look for condensing coil surfaces that are white or scaled or covered with dust and oil or debris, all of which are all signs of a system that has not been properly maintained.
- Check for (feel and listen) air leaks around exposed ductwork (roof curb for the rooftop unit). Ductwork may also have come apart inside the building. Typically, this is found above ceiling spaces and requires access to attics or ceiling spaces.
- Check refrigerant line sets to ensure they are adequately protected on split systems and packaged roof top units. Low-pressure suction lines should be insulated for efficiency.
- Check for signs of oil leaks or drips from the refrigeration system or components of the unit. Outdoor or indoor coils with Freon leaks may exhibit signs of oil and dirt that is accumulating on the oil. This type of problem may require more training on how to properly handle refrigerant and should only be done by an authorized person.
- Check that suction line insulation is installed to prevent condensation from forming (also an energy efficiency impact). Generally 3/8-in. wall thickness of Armaflex or equivalent is satisfactory. In severe applications (hot, high humidity areas), greater thickness may be required. Apply suction line insulation by sliding it on the sealed tubing before cutting and making connections. Use tie wraps to secure the insulation.
- Check that line sets (suction and discharge lines) are protected when the lines route more than 10 feet from the building to the outside unit. Damage from proximity to walkways, lawn equipment, etc. can damage the lines (partial crimping, pin holes, etc.), resulting in flow restrictions or refrigerant leaks.

Building Walk-down – HVAC Systems: Visual Inspections (Cont.)

- P-Trap installed and primed correctly?
- Indoor and outdoor coils clean?
- Refrigerant charge correct?

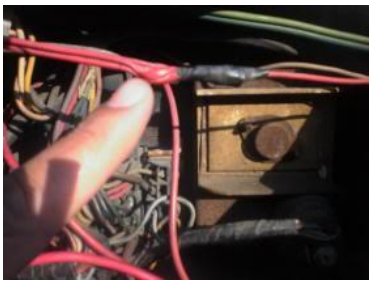
06 Investigation Phase – Building walk-down HVAC Systems

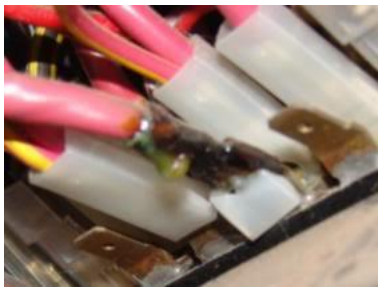
HVAC Systems – prescriptive checks

- Check the P-trap on the cooling coil. The P-trap should have water in it. Put your finger on the outlet of the P-trap, and even if the fan is running you should **not feel** any air moving in or out of the P-trap. If you feel air moving in or out of the P-trap, then the P-trap is dry. Remove the coil cover and pour water into the P-trap. Ensure trap drain lines are adequately sized if multiple RTUs are connected to a common header and not double trapped.
- Check to see if the outdoor coil is clean. It is easy to see debris against the outdoor coil and to clean. Accessing the indoor coil (and cleaning) may be more difficult.
- Check to see if the refrigerant charge is correct. Coils and filters should be cleaned to ensure proper air flows before taking temperature readings. Generally, most split systems that are properly charged are designed for a 20°F delta T. If the leaving air temperature is 55°F, the return-air temperature should be 75°F, but this is not always the case. The split may or may not be the same for packaged systems, and when the packaged design is more than one compressor/coil, this is probably not the case.
- Check the vendor's manuals for proper (design) air flow/pressure drops and required refrigerant charge (don't guess). A trained, EPA-certified HVAC technician should be used to correct refrigerant charge issues (adding or removing Freon refrigerants) and comply with EPA requirements when working with ozone-depleting substances (ODSs).

BUILDING WALK-DOWN – HVAC SYSTEMS: VISUAL ELECTRICAL INSPECTIONS (CONT.)

- BURNT WIRES?
- LOOSE TERMINATIONS?
- UNDER-SIZED WIRING?
- SAFETY ISSUES, EXPOSURE TO ENERGIZED HAZARDS, LOCK & TAG?





06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – visual electrical checks

- Check the electrical breakers and/or disconnects that provide power to the compressors and fans. Make sure all breakers and disconnects are turned on. Tripped breakers could be indicative of equipment problems. Always ask if unsure (trained maintenance staff should be the only staff to turn breakers or disconnects back on).
- Check for jumpers that might be put in place to bypass equipment sequencing (activate electric heat instead of heat pump compressor heat). This could be indicative of compressor failure(s) that occurred in a previous heating season.
- Look for burnt or disconnected wiring/electrical components. Smell for burning wires or burning oil. Burnt wires are a sign that the connection is loose or the wire was undersized for the load.
- Check for loose electrical wiring. Tightening of electrical connections is something that should be done during regular maintenance. These connections are generally a screw/lug type of connection that can be tightened with a screwdriver or "Allen-head" wrench.

ALWAYS FOLLOW ALL SAFETY RULES WHEN WORKING WITH ENERGIZED, ROTATING EQUIPMENT!

LOCK &TAG REQUIREMENTS SHOULD ALWAYS BE FOLLOWED!

BUILDING WALK-DOWN – HVAC SYSTEMS: VISUAL INSPECTIONS OF THE REFRIGERANT SECTION(CONT.)

- PROPER REFRIGERANT CHARGE?
- PROPER ELECTRICAL LOAD?
- ELECTRICAL COMPONENTS WORKING CORRECTLY?
- CRANKCASE HEATER WORKING CORRECTLY?
- LUBRICATION OF ALL ROTATING PARTS?

06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – prescriptive checks

- Check the refrigerant charge using manufacturer recommended procedures. This should be performed by a certified, trained professional. For best results, the refrigerant charge should always be checked with clean filters and clean coils (indoor evaporator and outdoor condenser coils). Otherwise, it's a guess.
- Check the current (amp) draw for the compressor motor and the condenser fan motor. This should be done by a trained professional. If the current draw is exceeding the motor nameplate rating, this could indicate a potential problem and should be noted.
- Check the compressor's crankcase heater with a temperature gun when the compressor is not running. If the temperature is close to the surrounding ambient temperature during a mild day it probably is not working. Check the amp draw to validate, if necessary.
- With the power off, lubricate the condenser fan and check the bearing for tightness.
- Check the contactors or motor controls to ensure all relays and contactors are working properly (listen – there should be no chattering). This may require "exercising" the system from the thermostat or control system for the different stages of heating and/or cooling.
- Check the run/start capacitor(s) for any motor-driven equipment (compressor or outdoor fans) to ensure that they are not leaking oil or bulging (a sure sign of imminent failure).
- For best results, the refrigerant charge should always be checked with clean filters and clean coils (indoor evaporator and outdoor condenser coils). Otherwise, it's a guess.
- Always exercise caution and safety when working around energized components.
- Follow all applicable safety rules and use good judgment around rotating equipment.
- Lock Out/Tag Out when required - **ALWAYS FOLLOW ALL SAFETY RULES WHEN WORKING WITH ENERGIZED, ROTATING EQUIPMENT! USE GOOD JUDGMENT AND EXERCISE CAUTION.**

BUILDING WALK-DOWN – HVAC SYSTEMS: VISUAL INSPECTIONS OF THE FAN SECTION

- WHAT TYPE OF INDOOR FAN IS INSTALLED?
- IS THE INDOOR FAN A DIRECT DRIVE, OR IS THE FAN DRIVEN WITH BELTS?
- ARE THERE SIGNS OF BELT FAILURE?
- ARE THERE SIGNS OF POOR MAINTENANCE?

06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

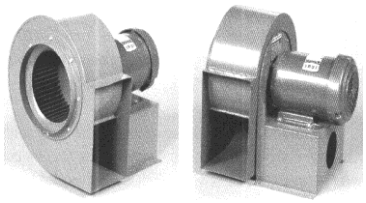
HVAC Systems – prescriptive checks

Check to see if the indoor fan is a direct drive fan or a belt drive fan.

- If it is a belt drive fan, correct belts, fans and other components should be verified with the vendor's manuals when replacing (don't guess).
- Direct drive fans will have the motor-mounted in the fan housing.
- Belts driven fans will have the motor-mounted outside of the fan housing on a base that is near the fan housing.
- Check for debris in the fan wheel and in the fan section.
- Check for insulation that has come loose and is hanging or fallen down inside the fan housing or ductwork.
- Check for signs of belt debris indicating that the belt is failing.
- Check for loose screws or bolts. If screws are found lying on the roof or next to the unit or on top of the unit (instead of being installed to secure the access door panels), this could lead to a loose door panel, allowing unwanted outside air to infiltrate into the unit (adding to the cost to provide conditioned air in the heating or cooling/de-humidification seasons).

BUILDING WALK-DOWN – HVAC SYSTEMS: VISUAL INSPECTIONS OF DIRECT DRIVE FAN MOTORS

- INSPECT THE FAN MOTOR, FAN WHEEL, FAN HOUSING
- CHECK THE FAN MOUNTS
- LUBRICATE BEARINGS AND CHECK FAN BEARINGS FOR TIGHTNESS
- ENSURE THAT THE FAN IS ROTATING THE CORRECT DIRECTION (WHEN MOTOR IS ENERGIZED)
- USE SENSES TO FIND PROBLEMS (LOOK AND LISTEN)



HVAC Systems – prescriptive checks

- Direct drive fans will have the motor mounted in the fan housing.
- Check that replacement components comply with the vendor's manuals.
- Check motor mounts. If they are loose, they can cause excessive noise and vibration that may be heard in office spaces via the diffuser/ducts.
- Check for debris in the fan wheel and in the fan section.
- Check for insulation that has come loose and is hanging or fallen down inside the fan housing or ductwork.
- Check for correct motor rotation after replacing the motor or updating wiring in the building. Three-phase motors can rotate backwards when two phases are inadvertently reversed.
- Check the bearings. Some fans and motors have self-lubricating bearings, but others will require periodic lubrication per the vendor's instructions.
- Check for special-purpose exhaust fans and their controls. If not controlled properly, these can increase the heating or cooling load on a building, especially if they run all night or all weekend while the building is unoccupied. If an exhaust fan is running when not required, there may not be any makeup air to accommodate the air being exhausted, and this will results in air infiltrating into the building. This can bring in dust, humidity and also cause temperature problems that result in the HVAC systems running more often than would be required if the exhaust systems were automatically turned off at night (when the building becomes unoccupied).

Building Walk-down – HVAC Systems: Visual Inspections of Belt Driven Fan Motors

- Inspect fan components
- Inspect fan mounting, bearings and rotation
- Are there audible signs of belt failure?
- Are there excessive vibrations?

HVAC Systems – prescriptive checks

- Belts driven fans will have the motor mounted outside of the fan housing on a base that is near the fan housing.
- Check that the fan motor, fan wheel, fan housing and belts are all intact.
- Check that the fan mounting brackets are tight, not loose.
- Check the bearings. Are they lubricated? Are they running cool or hot?
- Check the pulley and sheaves. Are they in good condition and in proper alignment?
- Check for debris in the fan wheel and in the fan section which indicates a belt is about to fail.
- Check for insulation that has come loose and is hanging or fallen down inside the fan housing or ductwork.
- Check for correct motor rotation after replacing the motor or updating wiring in the building. Three-phase motors can rotate backwards when two phases are inadvertently reversed.
- Check the bearings. Some fans and motors have self-lubricating bearings, but others will require periodic lubrication per the vendor's instructions.
- Check to ensure that a belt guard is in place to protect loose clothing from being entangled in the rotating belt and pulley. **Be careful if this condition is found!**
- **Different belts can be used on belt-driven equipment. Some have energy advantages over others, but also require greater care when installing. Poor alignment may result in excessive noise and other problems.**

Building Walk-down – HVAC Systems: Visual Inspections of the Coil Section

- Condition of the indoor/outdoor coils and fins
- Is the coil damaged?
- Is the indoor drain pan properly trapped and working?
- Is the temperature difference across the coil adequate when cooling?

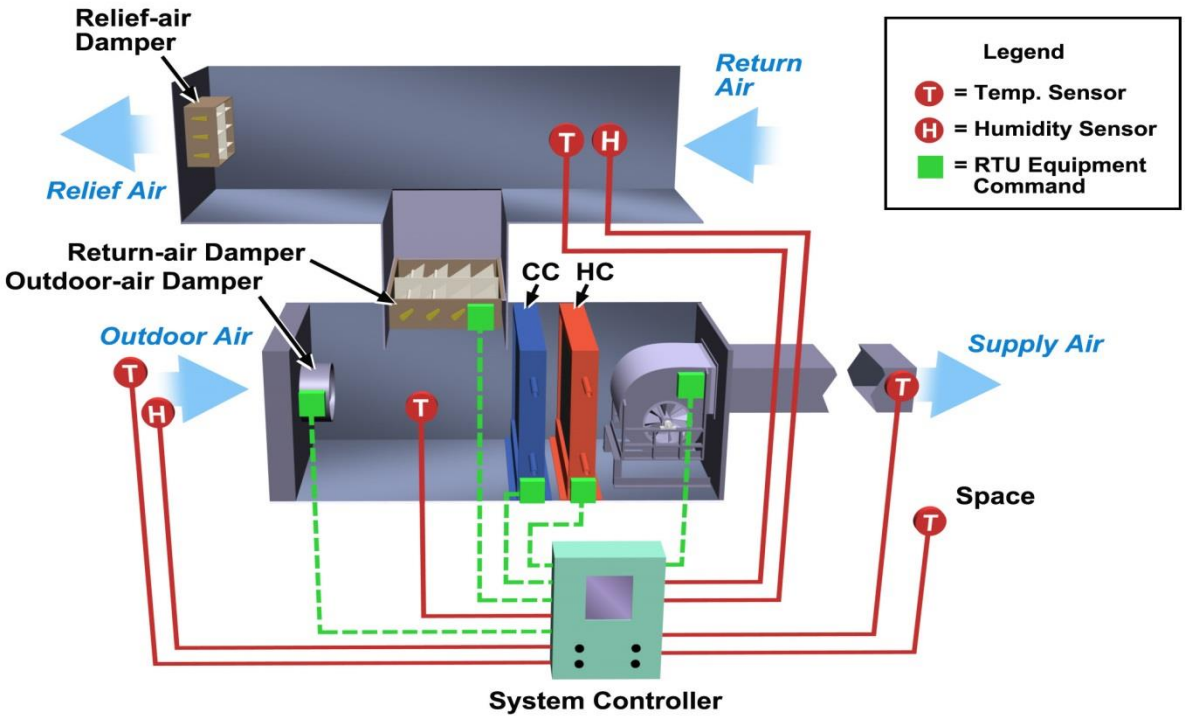
06 Investigation Phase – Building walk-down HVAC Systems

HVAC Systems – prescriptive checks

- Follow vendor recommendations for cleaning agent(s) and application for indoor evaporator coil and outside condenser coil cleaning. Wear appropriate personal protective equipment (PPE) for eye and skin protection. Also beware of any fumes that could be generated and ventilation requirements.
- Be careful not to damage coil fins when spraying down with water solution, and always be sure water is draining out the drain pan and connecting P-trap; otherwise, water may backup or find its way into the building, possibly causing water damage, etc.
- A dirty filter and/or dirty coil can cause the evaporator coil to freeze, and this can lead to compressor damage (flood back of liquid). Clean coils and filters are critical to safe, efficient equipment operation.
- Coils should be rinsed with a spray application in the opposite direction of normal air flow. For the typical "A-frame" coil (picture shown), this is determined by the fan location and discharge direction (up flow or down flow).
- Drain pans should be checked to ensure they are not clogged with debris and water is able to flow freely. Traps should be primed with water and installed correctly. Drain lines should be pitched correctly.
- **NOTE: to take pre-caution and care when cleaning with caustic or strong cleaning agents (skin/burn issues)**

BUILDING WALK-DOWN – HVAC ECONOMIZER FUNDAMENTALS

The Basics of Air-side Economizers

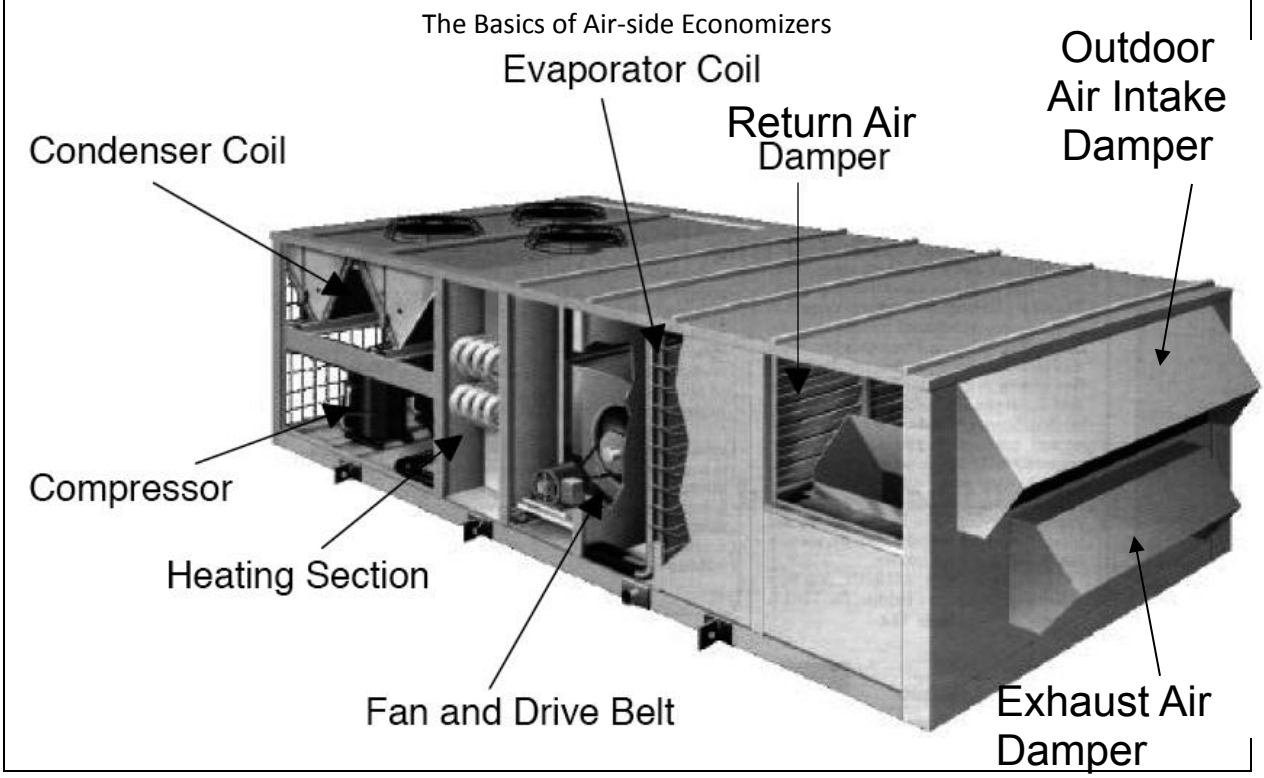


06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – Economizer Descriptions

- Air-side 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*)
- Air-side 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 ductwork on a central air-handling unit (AHU) or on a packaged roof top unit.
- 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).
- Typically automatic controls will operate the economizer cycle automatically, based upon some type of dry-bulb (sensible) or enthalpy (sensible + latent) control scheme (outdoor air or differential comparison).

BUILDING WALK-DOWN – HVAC ECONOMIZER FUNDAMENTALS



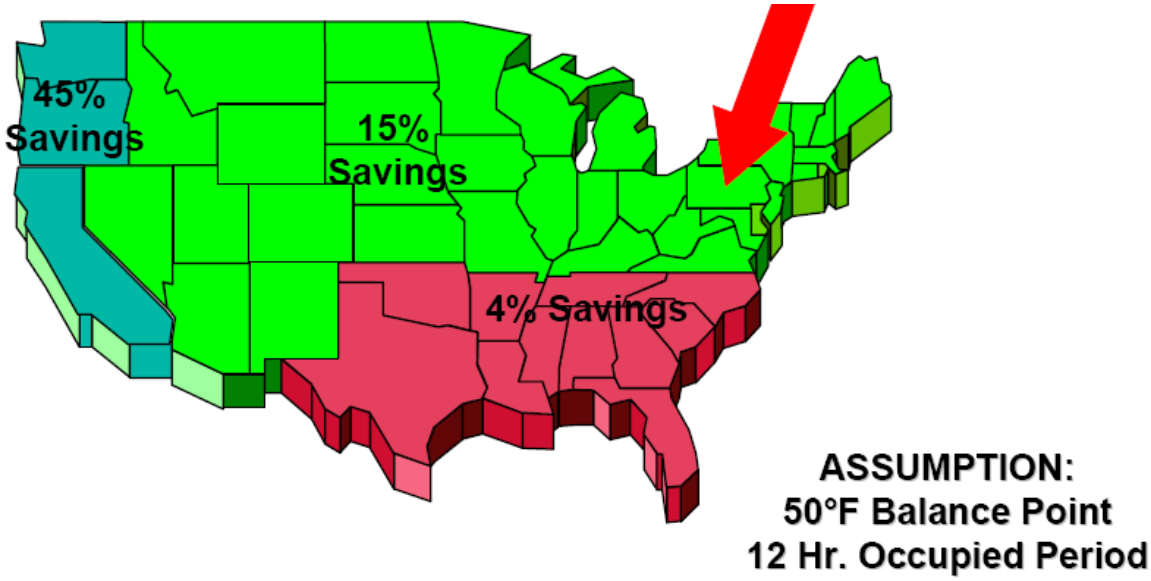
06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – prescriptive checks

- Although this is a common exhaust air and outdoor-air intake arrangement, provided by the manufacturers, it could lead to short circuiting of exhaust air to the intake.
- Check for leaking damper seals, poor construction and high temperatures on dark roofs. These all can contribute to economizer problems (entering air temperatures or mixed-air temperatures that are higher than desired).
- Air-side economizing uses unconditioned outdoor air to cool (or heat) a space.
- There are two air streams that are used to make up the supply air - outdoor and return air.
- Check that the dampers sequence together to mix and balance air streams to match the needs of the unit discharge conditions.
- As long as the outdoor air has lower heat content than the return air, it should be used even if mechanical cooling is required.
- In humid climates, use economizers when outdoor air is 5°F to 10°F below return-air temperature (dry-bulb control).

Building Walk-down – HVAC Economizer Savings Check of Enthalpy Controller

Should I consider a High Limit Enthalpy Controller? Approximately 15% Savings Difference

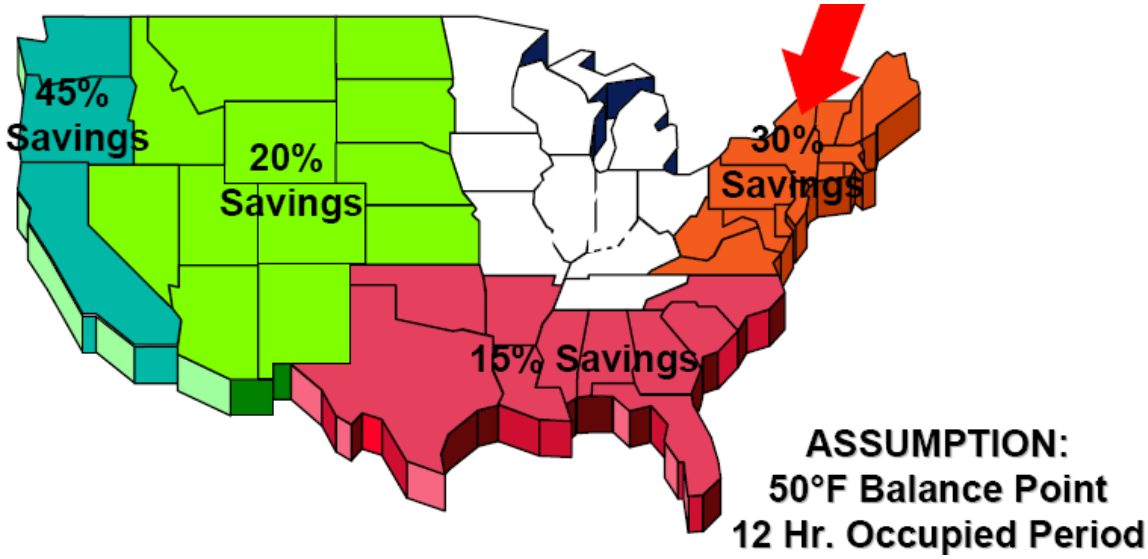


Source: Honeywell Controls

06 Investigation Phase – Building walk-down HVAC Systems

Building Walk-down – HVAC Economizer Savings Check of Enthalpy Controller

Differential Enthalpy Control Savings



Source: Honeywell Controls

BUILDING WALK-DOWN: HVAC ECONOMIZER SECTION – COMMON PROBLEMS

- A BROKEN ECONOMIZER LINKAGE RENDERS THE ECONOMIZER INOPERABLE!
- JAMMED OR FROZEN DAMPER?
- CONTROLLER FAILURE? ACTUATOR FAILURE? SENSOR FAILURE?
- MECHANICAL OR ELECTRICAL?

06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – prescriptive checks

- Check for disconnected or broken linkage.
- Verify economizer damper linkage was not disconnected for other reasons (failure of the actuator in energy intensive position – wide open).
- Check for jammed or frozen outdoor-air damper – lubricate moving parts if frozen.
- Check for non-functioning actuator, installed incorrectly or disconnected wire – fix or replace if failed.
- Check for malfunctioning outdoor-air/return-air temperature sensors.
- Check for a malfunctioning controller.
- Check for faulty control setting in the controller or thermostat and adjust to correct value.
- Is it a stand-alone controller (Honeywell Sensible or Enthalpy Controller) or is it integrated to the thermostat?
- Is the actuator pneumatic or electric? If pneumatic, is there instrument air to the device and the controller (20-25 PSI is the usual minimum control instrument air pressure requirement). If electric, does the actuator have a dedicated or shared 24/120 VAC power source (usually from a transformer or dedicated power circuit). If not, the electric actuator will not respond to any control signal from the thermostat, controller or other source.
- Is the minimum damper set point for either type of controller the correct value and how do you validate the actual fraction of outdoor air (percent)?

- Are the dampers at their minimum position (when it is appropriate)? Calculate the outdoor-air fraction by taking three temperature readings to validate the minimum damper position control is working. This includes the return-air temperature (RAT), mixed-air temperature (RAT) and outdoor-air temperature (OAT).

- The equation for this is as follows: [(RAT-MAT) / (RAT-OAT)] * 100. For example, if the temperatures recorded are: RAT = 72, MAT = 60 & OAT = 40, the equation would be [(72-60) / (72-40)] * 100 = [12/32] * 100 = 37.5% open. Normally, minimum damper settings would not be more than 10-20% open. This might indicate an RTU that is over-ventilating when the damper is at its minimum setting and in need of some adjustment.

- Why is this important? If the minimum outdoor ventilation required is only 10% by code and the rooftop unit or air handling unit is bringing in additional outside air during cold or hot/humid weather, this will require additional energy to either heat or cool (and possibly de-humidify).

- Demand Control Ventilation (DCV) may be one opportunity to consider for possible improvement (unless the existing thermostat or digital controls already have this capability incorporated in the controls). DCV (depending upon the design requirements required by local energy codes) allows for using one or more sensors to measure Carbon Dioxide (CO_2) in the space being ventilated. Based upon the measured readings (Parts Per Million – PPM), and the required minimum or required difference when compared to some known outside ambient value, the outdoor-air dampers may be allowed to remain closed or mostly closed as compared to standard ventilation controls.

BUILDING WALK-DOWN: HVAC SYSTEM CONTROLS – THERMOSTATS

- TYPE OF THERMOSTAT?
- CONFIGURED CORRECTLY? IF THE THERMOSTAT IS DIGITAL PROGRAMMABLE, WHAT FEATURES DOES IT SUPPORT?
- 7-DAY SCHEDULING? SET POINTS? HOLIDAY SCHEDULING? OPTIMAL START/STOP? REMOTE SENSORS?
- IF AN OUTDOOR-AIR SENSOR IS USED, WHERE IS IT LOCATED?
- THERMOSTAT LOCATION ISSUES (DRAFTS, SUN, SOURCES OF HEAT, FALSE READINGS)?
- SPECIAL HVAC FUNCTIONS (HEAT PUMPS, ECONOMIZERS, EXHAUST/RELIEF FANS)?
- CHECK MANUFACTURER SETUP INSTRUCTIONS AND RECOMMENDATIONS

06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – prescriptive checks

- Check for the type of thermostat. Is it mechanical or digital? If mechanical, replacing the thermostat with a digital thermostat will save money (if properly configured). If the mechanical thermostat is left in place, ensure it is configured for acceptable set points.
- Check the different types of thermostats and document them as part of the walk-down. Get the model and serial numbers of each thermostat. These numbers can be used to find out what the functions and capabilities are that can be programmed into the thermostat.
- Check to see if the programmable thermostat has optimal start (intelligent recovery) capability. Many thermostats have optimal start capability without the use of an outdoor temperature or enthalpy sensor.
- Check to see if an outdoor-air temperature sensor is used. If so, where is located? Ideally the outdoor-air temperature sensor needs to be located on the north side of the building, but in a shield/solar protection device, or it should be in the shade at all times.
- Check to see if the programmable thermostat has a second stage lockout set point (common for heat pumps). Each manufacturer may have slightly different methods to their programmable features inside of their thermostats. Check each thermostat and know the features that can be programmed and verify that they are configured properly.

- Check to see what scheduling capabilities are included with the thermostat (5+2, 5+1+1, or 7-day schedule)?
- Check to see if holidays be scheduled? Although this feature is not common, it is something to look for as this is becoming more common in newer thermostat features.
- What are the start and stop times for the schedule in the thermostat? Note the schedules in your walk-down report. Are they different for the weekends or the same? Note the weekend schedules for the report.
- Check to see if the schedules match when the building is truly occupied or if they reflect other issues (lack of confidence in the HVAC systems to recover adequately, erratic occupancy patterns, extreme weather events, etc.).
- Check to see when the building is truly occupied and not when it is scheduled to be occupied. Let the programmable thermostat's optimal start feature (if provided) determine the optimum start time. Resist the urge to configure scheduled start times significantly earlier than the expected occupancy time, just to satisfy "periodic" extreme weather events for the heating and cooling needs.
- Check to see if the difference between the occupancy times and scheduled times are varied by more than 2 hours. For instance, when the occupancy time for the building is 6 AM and the scheduled start time is 2AM – 3AM (or earlier), this is a good application for installing a programmable thermostat with optimal start (intelligent recovery) capabilities.
- Does the thermostat have temporary override capabilities? Note the temporary override time for the report. This needs to be used for after-hour operations (working late, janitorial, overtime, etc.). If it is used, it should be configured to only provide 1 to 2 hours of equipment operation during the activation of the override, and not allow for an "infinite" time (no expiration) override.
- Check the heating and cooling set point values. They should have at least a 2^{o}F dead band (or greater) between the set points during occupied periods (example, heating = 72^{o}F and cooling = 75^{o}F) and at least 20^{o}F dead band (or greater) between the set points during unoccupied periods (example, heating = 62^{o}F and cooling = 82^{o}F).
- Check the thermostat location. It should not be located on an exterior wall or near a heat source or in direct sun light.
- If the thermostat controls auxillary equipment (exhaust fan, lighting, pump, etc.), verify that the controls are working correctly.
- If the thermostat has economizer control (outdoor and return-air dampers), verify that the economizer control is working correctly (introducing outside air when more effective than return air during cooling demands).
- Check if the thermostats are controlling other devices in the building and if they work correctly (i.e., exhaust fans, lighting, pumps). Look for additional pieces of equipment that the thermostat may be controlling. Today's thermostats can control more than just heating and cooling equipment. They may also control exhaust fans and lights; the list goes on and on for what a thermostat can do. Some thermostats might control the economizer inside of the heating and

cooling equipment. Note it and test this functional capability to make sure that it works properly with the thermostat. Proper operation of the economizer from a thermostat is for the outdoor-air dampers to open upon a call for cooling, when the outside air has less total energy than the return air. Depending upon the thermostat and HVAC units capabilities, the ability to determine which air stream has less energy may be limited to simple sensing techniques that look only at outdoor air dry-bulb temperatures. If this is true, the recommended outside air dry-bulb temperature, which would contain less energy for reduced cooling load on the HVAC unit, would be a setting of anywhere from 60°F to 70°F outside temperature (depending upon the geographical location and climate zone). Any settings above or below these values could be counter-productive.

- Check to see if that the thermostats are sensing the temperature of the area they serve, and are controlling the right piece of equipment in the area they serve. Test by turning the fan off and checking registers in the area; they should have no air flowing out of them.

- Are multiple sensors used to more accurately sense (average) the room temperature in a building? Some thermostats may have several wireless (or wired) temperature sensors connected to them. This feature is part of some of the new lines of thermostats on the market today. There are also some thermostats that can be controlled from an app on a smart phone or from a web page. These are features that one should be aware of and looking for in new thermostats. Make sure that additional sensors (wired or wireless) follow the same rules for locating thermostats (see above). More remote sensors will give the thermostat a more accurate reading of the building space temperatures, resulting in better space temperature control (hopefully fewer complaints).

- Re-tuning ideas
    - Digital thermostat that is programmable
    - Scheduling
    - Set points
    - Fan and economizer operations
    - Thermostat location
    - Remote sensors.

BUILDING WALK-DOWN: HVAC SYSTEM CONTROLS – THERMOSTATS

- CHECK THE LOCATION OF THE THERMOSTAT
- THERMOSTAT OVERRIDE (HOLD) FEATURE

06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – prescriptive checks

- Check the location of the thermostat.
- Check that the thermostat is not places close to a heat source or behind things that will impede the thermostats ability to sense the room temperature.
- Thermostats need to be located on the interior walls not on exterior walls, also not in direct sunlight.
- Is there a draft of air coming from behind the thermostat that will affect the temperature that the thermostat is sensing?
- Make sure there are no overrides on the thermostat ("Hold" feature) that prevent set back (unoccupied) actions from occurring.

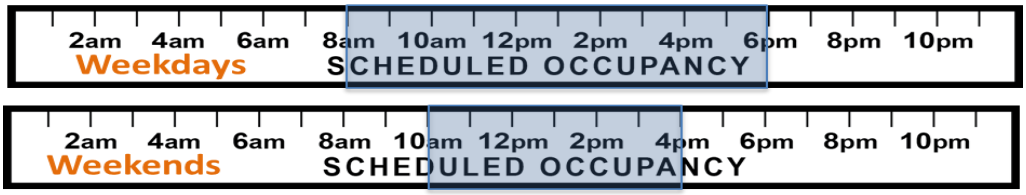
BUILDING WALK-DOWN: HVAC SYSTEM CONTROLS – PROGRAMMABLE THERMOSTAT SETUP

- WHAT TYPE OF SCHEDULING CAPABILITIES DOES IT HAVE?
- 5+2 – ONE WEEKDAY AND ONE WEEKEND
- 5+1+1 – ONE WEEKDAY AND TWO WEEKEND
- 7 – SCHEDULE FOR EACH DAY OF THE WEEK

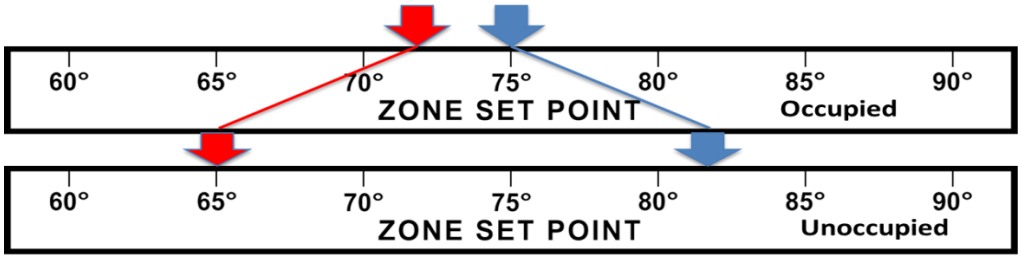
06 INVESTIGATION PHASE – BUILDING WALK-DOWN HVAC SYSTEMS

HVAC Systems – prescriptive check.

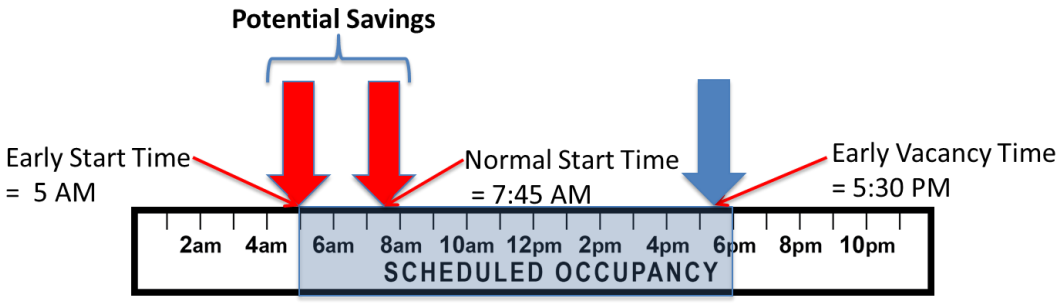
- Check the thermostats programmed weekday and weekend schedules (example shown here):



- Check the occupied and unoccupied heating and cooling set points (example shown here):



- Optimal start savings potential (example shown here):



- Check the thermostat capabilities. What scheduling capabilities does the thermostat have? 5+2, 5+1+1, or 7 Day type of day schedule? Can holidays be scheduled? Although this feature is not common it is something to look for in the building walk-down.

- What are the start and stop times for the schedule? Note the schedules for the report? Is it different for the weekends or the same? Note the weekend schedules for the report. Does it match when the building is truly occupied?

- Watch the building to find when the building is truly occupied and not when it is scheduled to be occupied. Let the optimal start feature (if provided) determine the optimum scheduled start time. Do not configure the scheduled start times for the HVAC unit so early just to satisfy a "once-a-year" weather event for the heating and/or cooling needs.

- Does the thermostat have temporary override capabilities? Note the temporary override time for the report. This needs to be used for after-hours operations (working late, janitorial, overtime, etc.). If it is used, it should be configured to only provide 1-2 hours of equipment operation during the activation of the override, and not allow for an "infinite" time (no expiration) override.

- What are the set points for occupied and unoccupied? There should a minimum 5^{o}F (or greater) difference between occupied and unoccupied temperature set points. Occupied set points should have a 2^{o}F or greater dead band between heating and cooling temperature set points. For example: Heating set points = 72^{o}F, (occupied) and 65^{o}F (unoccupied), and cooling set points = 75^{o}F (occupied and 82^{o}F (unoccupied). This equates to a 3^{o}F occupied dead band during occupied periods and a 7^{o}F difference between the occupied and unoccupied temperature set points.

BUILDING WALK-DOWN: HVAC SYSTEM CONTROLS – PROGRAMMABLE THERMOSTAT FAN CONTROL

- DOES THE THERMOSTAT FAN OPERATION CYCLE ON CALLS FOR HEATING OR COOLING DURING OCCUPIED MODE OR RUN CONTINUOUSLY DURING THE OCCUPIED MODE?
- CONFIGURED CORRECTLY? MINIMUM VENTILATION CODE REQUIREMENTS BEING MET?

HVAC Systems – prescriptive checks

- Is the programmable thermostat in "Fan-Auto," which means that the fan is cycling with the cooling compressor and/or furnace?
- If the thermostat is in "Auto," (instead of "On" or "Run" in Occupied Mode), it can lead to lower ventilation rates than required, especially during spring and fall seasons, when cooling/heating needs are at a minimum.
- Commercial building codes may require the RTU fans to be running continuously to provide adequate ventilation during occupied modes.

QUESTIONS?

?

- Ask if there are any questions.

Chapter 7: Investigation Phase: Lighting Systems and Controls

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN HOW TO WALK DOWN THE LIGHTING SYSTEMS OF A BUILDING

MATERIALS: POWERPOINT SLIDES 07 LIGHTING SYSTEMS AND CONTROLS INVESTIGATION PHASE

LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN REVIEWING INTERIOR LIGHTING
- WHAT TO FOCUS ON WHEN REVIEWING EXTERIOR LIGHTING

07 RE-TUNING STEPS

BUILDING WALK-DOWN: INSIDE LIGHTING SYSTEMS AND CONTROLS

- INTERIOR CONTROLS - MANUAL SWITCHES, OCCUPANCY SENSORS, DIMMERS OR TIME CLOCKS?
- TYPE OF LIGHTS (T-12, T-8, T-5. LED, CFL, INCANDESCENT?)
- PROPER LIGHT LEVELS BEING MAINTAINED OR OVER-LIT?
- OPPORTUNITY TO DE-LAMP?
  - USE LIGHT METER TO VERIFY IF LIGHT LEVELS MEET IES OR SIMILAR GUIDELINES
  - ARE THERE DAY-LIGHTING OPPORTUNITIES?
  - ARE SIGNS POSTED AT MANUAL LIGHT SWITCHES?
  - ARE FIXTURES AND LAMPS CLEAN?

07 INVESTIGATION PHASE – BUILDING WALK-DOWN LIGHTING SYSTEMS

Lighting Systems and Controls – prescriptive checks

- Check to see if minimum light levels are being maintained. Use a light level meter to ensure that the light fixtures are not over lighting the building.
- Check for older lighting systems. Replace T-12 lamps with T-8s or T-5s. Some T-12s are no longer being manufactured and replacement costs are significantly increasing. Group re-lamping may be the most efficient and economical way to undertake this effort. Consider LEDs for applications where total cost is considered. LEDs can last significantly longer than any other lighting technology and may be especially beneficial in hard-to-reach areas or high labor cost areas.
- Check light fixtures and lamps for cleanliness. Clean light fixtures if dirty. If the light fixture is dirty, there is a reduction in the light output effectiveness. As lamps age, their light output effectiveness also decreases.
- Check for incandescent light bulb use. Use compact fluorescent lamps (CFLs) in place of incandescent bulbs where it makes sense.
- Check for occupancy sensors in locations where it makes sense. Occupancy sensors can work well in conference rooms, bathrooms and office spaces. Bathroom occupancy sensors need to control the bathroom exhaust fans, when possible.

- Check to see if existing occupancy sensors are working properly, and turn off equipment as intended. For spaces that have low occupancy patterns, this might be something that would make sense for these areas from a first cost basis.
- Check that occupant awareness (signs) is located at all manual switches that direct occupants to save energy by turning lights off when they leave. This is a very effective way to promote energy awareness.

BUILDING WALK-DOWN:OUTSIDE LIGHTING SYSTEMS AND CONTROLS (CONTINUED)

- EXTERIOR CONTROLS – PHOTO CELL EYES, MANUAL SWITCHES OR TIMER/CLOCKS?
  - TYPE OF LIGHTS USED OUTSIDE FOR PARKING AND OTHER EXTERIOR SPACES?
  - NUMBER OF LIGHTS
  - PHOTO-CELL CONTROL, TIME CLOCK OR OTHER CONTROL SYSTEM?
    - PHOTO-CELL WORKING CORRECTLY?
    - EXTERIOR LIGHTS STAYING ON TOO LONG OR COMING ON TOO EARLY?



07 INVESTIGATION PHASE – BUILDING WALK-DOWN LIGHTING SYSTEMS

Lighting Systems and Controls – prescriptive checks

- Check light fixtures and lamps for cleanliness. Clean light fixtures if dirty. If the light fixture is dirty, there is a reduction in the light output effectiveness. As lamps age, their light output effectiveness also decreases.
- Reduce exterior lighting power density (LPD) and parking area lighting. Do you need all of the lights on the outside of a building on? There is usually an opportunity to reduce this lighting or turn it off because this lighting may only be needed for a small part of the night. In many cases, the lights are used for employee safety and possibly building security.
- Use photo cells to control parking lots and exterior lights. It is preferable to use an astrological clock for controlling the outside lights, if the clock is not complicated and if it is reliable.
- Check that the photo cell sensor eye is “clean”, not obscured by landscaping or in a location that will cause a false reading (resulting in lights being on all the time, or potentially off all the time).

QUESTIONS?

07 INVESTIGATION PHASE – BUILDING WALK-DOWN LIGHTING SYSTEMS

- Ask if there are any questions.

Chapter 8: Investigation Phase: Hot Water Systems and Controls

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN HOW TO WALK DOWN THE HOT WATER SYSTEMS OF A BUILDING

MATERIALS: POWERPOINT SLIDES 08 HOT WATER SYSTEMS AND CONTROLS INVESTIGATION PHASE

LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN REVIEWING DOMESTIC HOT WATER SYSTEMS
- WHAT TO FOCUS ON WHEN REVIEWING HEATING HOT WATER SYSTEMS

08 RE-TUNING STEPS

BUILDING WALK-DOWN: HOT WATER SYSTEMS AND CONTROLS

- TYPE OF HOT WATER SYSTEM – DOMESTIC HOT WATER OR HEATING HOT WATER OR BOTH?
- ENERGY STAR RATED APPLIANCES?
- DOMESTIC HOT WATER TEMPERATURE SET POINT?
- HEATING HOT WATER TEMPERATURE SET POINT?
- HOT WATER PUMP CONTROLS/VFD DRIVEN?
- HOT WATER PUMPS OFF AT NIGHT?

08 INVESTIGATION PHASE – BUILDING WALK-DOWN HOT WATER SYSTEMS

Hot water systems – prescriptive checks

- If the system serves domestic hot water (used for washing hands and for showers), check the set point and the actual temperature. What set point is required? Can the current set point be lowered and still meet the requirements for the use?
- If the system serves heating hot water for perimeter (baseboard) or fan (heating coil) heating, check the set point and the actual temperature. What set point is required? Can the current set point be lowered and still meet the requirement for the use? Some boilers are not designed to operate with water temperatures below 140^{o}F, and this may include set back periods (check with the vendor's startup, operations and maintenance instructional manual).
- Determine if the hot water system appliance (tank or boiler) is gas or electric or other (solar, wood-fired, etc.). If gas, is the pressure regulator set correctly? Is the tank "Energy-Star" rated?
- Check to see if electric hot water heaters can be turned off at night. Do the circulating pumps turn off at night?
- Check if these systems have a circulating pump. Does the circulating pump work and is it pumping during occupied mode? To test if the pump works, is the return line from the building warm or cold? If it is cold, the pump is not pumping (or the appliance has failed or is set too low). If the line is warm, the pump is pumping water.
- Check if there are any controls for the circulating pumps. Do they respond to schedules, set points or other variables? Does the circulating pump have a variable frequency drive? If yes, does it vary its speed in response to load or time-of-use changes?

Building Walk-down: Hot Water Systems and Controls (continued)

- Are the tanks insulated?
- Are the plumbing lines insulated?
- Are there any observable leaks? Faucets leaking? Relief valves leaking?
- Zone heating controls in place and working?
- Set back controls in place and working?
- Summer heating Shutdown in place?

08 Investigation Phase – Building walk-down Hot water Systems

Hot water systems – prescriptive checks

- Check the hot water set back control: Some hot water heating systems (gas-fired) cannot be turned off at night. If the hot water heating system has a standing pilot (manually lit), it may fail because of cold morning start-up problems (due to condensation on the pilot flame, extinguishing it). If it has an automatic (direct) ignition start-up system there is a pretty good chance that it can be turned off at night without causing any significant problems.
- Check to see if the heating system remains off during the summer or runs year-round? If it runs in the summer, determine why.
- If a time clock is used to control the hot water heating system, check to make sure that the time clock is still operational and that it is set to the correct time (power outages over time can cause these clocks to be off by several hours, unless they have battery backup capability). Set the time clock close to a time that is it supposed to turn off, and make sure that the pump and hot water heaters turn off. If battery backup capability exists, are the batteries working?
- Check to see if holding (storage) tanks, connected piping and hot water heaters are all properly insulated. In some areas, you can get additional insulating blankets to improve the insulation quality of the tanks.
- Check that the piping system and fixtures at the point-of-use locations (sinks, etc.) are not leaking (adding load to the hot water systems when loads do not exist) and operate correctly. Dripping faucets and leaking pipes can add additional load to the water heaters and are a source of wasted water.

- Can the system be turned off at night or when not in use? Determine why the hot water systems cannot be turned off, and document for the report. If they can turn off do they turn off when they are suppose too (based upon occupant schedule, or when there is not production going on inside the building)?
- Re-tuning Suggestions
    - Turning off hot water tanks at night or when not needed (if possible)
    - Hot water temperature set point too high – turn it down (if possible)
    - Turn pumps off at night or when not needed (if possible). If VFD-driven, reduce pump speed at night or during low loads
    - Verify pumps are pumping when needed
    - Replace/add insulation, where missing (tanks and piping)
    - Fix leaks at faucets, appliances or piping
    - Solar or other "green" technologies – proper interface to existing systems.
- **Maximum hot water temperatures: Generally 120-140 for domestic hot water, 120-180 for heating hot water (seasonally adjusted)**

QUESTIONS?

08 INVESTIGATION PHASE – BUILDING WALK-DOWN HOT WATER SYSTEMS

- Ask if there are any questions.

Chapter 9: Investigation Phase: Office Equipment

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN HOW TO EVALUATE THE OFFICE EQUIPMENT DURING THE WALK DOWN OF A BUILDING

MATERIALS: POWERPOINT SLIDES 09 OFFICE EQUIPMENT INVESTIGATION PHASE

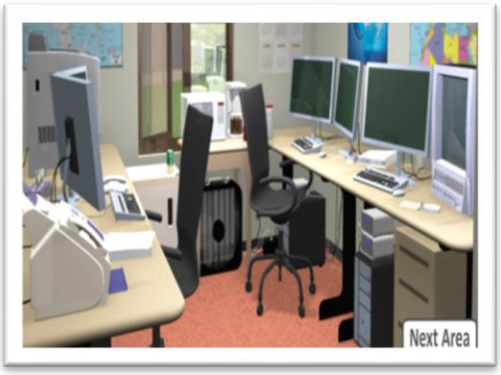
LEARNING OBJECTIVES:

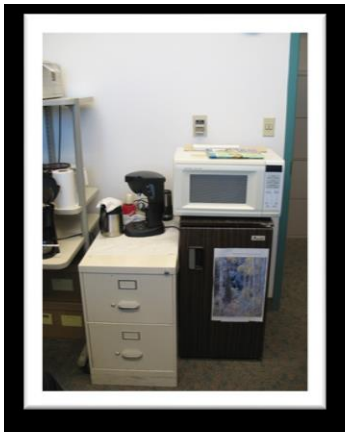
- WHAT TO FOCUS ON WHEN REVIEWING OFFICE EQUIPMENT

09 RE-TUNING STEPS

BUILDING WALK-DOWN: OFFICE EQUIPMENT

- ENERGY STAR RATED APPLIANCES AND COMPUTING RESOURCES?
- AUTOMATED OCCUPANCY SENSOR CONTROL?
- EDUCATE OCCUPANTS TO TURN OFF EQUIPMENT WHEN NOT IN USE (WEEKNIGHTS AND WEEKENDS)
- ARE PORTABLE SPACE HEATERS OR FANS RUNNING IN UNOCCUPIED SPACES – POTENTIAL IMPACT TO HVAC OR SAFETY?





09 INVESTIGATION PHASE – BUILDING WALK-DOWN OFFICE EQUIPMENT

Office Equipment – prescriptive checks

- Check to see if appliances and office equipment are Energy Star rated. This should include lunch room appliances (refrigerators, freezers, ovens, microwave ovens) and office equipment.
- Check for occupancy sensor-based outlet control. There are vendors who make occupancy sensor-based control outlets and outlet strips. The outlets can be installed for the rated circuit amp rating (15 or 20 Amps). These outlets can control loads up to the same load rating. The outlet strips should not be used for loads greater than 750 Watts (even though the vendors rate them up to 1500 Watts). This still allows for automatically turning off loads like coffee pots, printers, monitors, small fans and in some cases, portable heaters (depending upon the portable heater wattage rating and method used to automatically turn them off).
- Check computers for energy-saving mode configurations. Most computers provide for some level of energy savings when the computer is not in use. Is it being used? Do occupants know how to configure this?
- Check to see if portable heaters are being managed. They can be a fire hazard if located too close to combustible material in offices. They can also cause problems if they create false reading(s) for the local thermostats and/or averaging sensors. This leads to occupant complaints and can lead to occupants opening windows and other counter-productive activities. They should be managed accordingly.
- Educate occupants.

Building Walk-down: Office Equipment Occupancy Sensor Control

- Many vendors now make occupancy-sensor based plug load controllers
- These can be wall strip or outlet strip, designed for non-critical load management
- They usually have a built-in occupancy sensor and timer that can be adjusted to eliminate nuisance trips

09 Investigation Phase – Building walk-down Office Equipment

Office Equipment – prescriptive checks

- Check for occupancy sensor-based outlet control. There are vendors who make occupancy sensor-based control outlets and outlet strips. The outlets can be installed for the rated circuit amp rating (15 or 20 Amps). These outlets can control loads up to the same load rating. The outlet strips should not be used for loads greater than 750 Watts (even though the vendors rate them up to 1500 Watts).
- Check to see if portable fans are being managed.
- When occupants are on vacation or business travel for more than a few days, do they leave non-essential loads turned on (printers, lamps, lights, etc.)?
- Educate occupants!

Questions?

?

09 Investigation Phase – Building Walk-down Office Equipment

- Ask if there are any questions.

Chapter 10: Investigation Phase: Indoor Environmental Quality

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN HOW TO EVALUATE THE OFFICE ENVIRONMENT DURING THE WALK DOWN

MATERIALS: POWERPOINT SLIDES 10 INDOOR ENVIRONMENTAL QUALITY INVESTIGATION PHASE

LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN REVIEWING INDOOR ENVIRONMENTAL QUALITY

10 RE-TUNING STEPS

BUILDING WALK-DOWN: INDOOR ENVIRONMENTAL QUALITY

- MAKE SPOT MEASUREMENTS TO NOTE THE TEMPERATURES
- WHAT IS THE TYPICAL TEMPERATURE? DOES IT FEEL UNUSUALLY DRY OR HUMID?
- TALK TO PEOPLE TO GET THEIR VIEW ON THE GENERAL COMFORT IN THEIR ROOMS
- CHECK CONFERENCE ROOMS OR CORNER OFFICES - ARE THEY TOO HOT OR TOO COLD?
- OCCUPANT ACTIONS TO "IMPROVE" THEIR ENVIRONMENT?

10 INVESTIGATION PHASE – BUILDING WALK-DOWN: INDOOR ENVIRONMENTAL QUALITY

Indoor Environmental Quality – prescriptive checks

- Check the discharge-air diffusers. Are they fully or partially closed? Closed or partially closed diffusers are sure signs of occupant discomfort.
- Check for space heaters in offices, which may be a response to over-cooling or excess air flow.
- Check return air grills. Return grills can be in the walls, but are usually they are in ceilings. Make sure they are not covered. Return grills can be in doors. If the space was remodeled and new doors were installed, were the grills in the doors re-installed? If not, was a return path in the ceiling or wall provided?
- Check corner office spaces or similar spaces with two or more perimeter exposures. These locations can be problematic if not constructed or maintained correctly.

Building Walk-down: Indoor Environmental Quality

- Look at discharge air diffusers. Are they fully or partially closed?
- Closed or partially closed diffusers can be signs of discomfort
- Are the return air grills blocked or covered?
- Look for space heaters in offices
- Are there areas that are stuffy or have unusual odors?

10 Investigation Phase – Building walk-down: Indoor Environmental Quality

BUILDING WALK-DOWN: INDOOR ENVIRONMENTAL QUALITY

- A MUSTY SMELL OFTEN INDICATES THAT THIS AREA OF THE BUILDING IS NOT PROPERLY VENTILATED. THIS SITUATION MAY OR MAY NOT BE AN ENERGY ISSUE, BUT IT IS DEFINITELY A COMFORT ISSUE. IF THE BUILDING IS NOT PROPERLY VENTILATED, NOT ENOUGH FRESH OUTSIDE AIR IS COMING IN

10 INVESTIGATION PHASE – BUILDING WALK-DOWN: INDOOR ENVIRONMENTAL QUALITY

Indoor Environmental Quality – prescriptive checks

- Check for mold (which could indicate water problems or envelope problems).
- Check for sewer gases coming into the building via the ventilation systems (floor drains).
- Check for exhaust fans not running when they should be (fume management).
- Check for dead animal(s) in the building structure or ventilation systems.
- Are there areas that are stuffy or have unusual odors?

QUESTIONS?

?

10 INVESTIGATION PHASE – BUILDING WALK-DOWN INDOOR ENVIRONMENTAL QUALITY

- Ask if there are any questions.

Chapter 11: Investigation Phase: Air Distribution Systems

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN HOW TO WALK DOWN THE AIR DISTRIBUTION SYSTEMS OF A BUILDING

MATERIALS: POWERPOINT SLIDES 11 AIR DISTRIBUTION SYSTEM INVESTIGATION PHASE

LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN REVIEWING AIR DISTRIBUTION SYSTEMS (DUCTWORK)

11 RE-TUNING STEPS

BUILDING WALK-DOWN: AIR DISTRIBUTION SYSTEMS

- DUCTWORK INTEGRITY? LEAKING? PROPER CONNECTIONS AND JOINTS?
- IF BOTH THE SPACE(S) SERVED BY THE DUCTWORK AND THE AREA THAT THE DUCTWORK RUNS THROUGH ARE AT OR NEAR THE SAME TEMPERATURE, THIS COULD BE AN INDICATION OF A BIG LEAK – ESPECIALLY IF THE SPACE IS AN ATTIC OR UNOCCUPIED SPACE (MECHANICAL ROOM).
- ACCESS TO ATTICS AND CRAWL SPACES TO VERIFY DUCTS IS NECESSARY – BE CAREFUL WHEN IN THESE SPACES
- IS THERE DUCTWORK THAT IS CRUSHED OR FLATTENED?
- IS DUCTWORK SAGGING OR NO LONGER ATTACHED TO ITS SUPPORT HANGERS?
- DIRT/DUST TRAILS NEAR JOINTS OR SEAMS IN THE DUCTWORK?
- TAPE OR INSULATION NOT ATTACHED OR HANGING FROM THE DUCTWORK?

11 INVESTIGATION PHASE – BUILDING WALK-DOWN: AIR DISTRIBUTION SYSTEMS

Air Distribution System – prescriptive checks

- Check attics and crawl spaces to verify ducts, as necessary – be careful when in these spaces (animals, insects, heat, obstructions, etc.). Look for ductwork that is crushed or flattened, ductwork that is sagging or no longer attached to its support hangers, dirt/dust trails near joints or seams in the ductwork, tape or insulation that is not attached or hanging from the ductwork.
- Check that ductwork is sealed properly. Ductwork that is not sealed correctly can cause the building to become depressurized. This can allow unconditioned and unfiltered air into the building. This can lead to health problems for the occupants of the building. Improperly sealed ductwork can lead to comfort problems. Sometimes it will only show when the building is subjected to temperature extremes that are at or near the design temperature of the building design conditions. For new construction, <10% air loss is considered the “acceptable” expected air loss when putting in a new ductwork system (per SMACNA & ASHRAE)
- Check for ductwork that is crushed or flattened.
- Check for ductwork that is sagging or no longer attached to its support hangers.
- Check for dirt/dust trails near joints or seams in the ductwork (air leak).
- Check for tape or insulation that is not attached or hanging from the ductwork.

BUILDING WALK-DOWN: AIR DISTRIBUTION SYSTEMS (CONTINUED)

- AIR LEAKAGE MAY INCREASE OVER TIME BECAUSE OF:
- CONSTRUCTION (ADDING TO OR DISTURBING THE DUCTWORK)
- DAMAGE (MAINTENANCE/OTHER ACTIVITIES)
- EXPOSURE TO THE OUTDOOR ELEMENTS CAUSING DAMAGE TO THE DUCT MATERIAL
- OPERATIONAL CHANGES IN DUCT STATIC PRESSURE SET POINTS (INCREASED STATIC)

11 INVESTIGATION PHASE – BUILDING WALK-DOWN: AIR DISTRIBUTION SYSTEMS

Air Distribution System Air Leakage– prescriptive checks

- Studies show between 10% and 30% of the conditioned air (heated and cooled for comfort) is wasted because of leakage through ductwork.
- For new construction, <10% air loss is considered the "acceptable" expected air loss when putting in a new ductwork system (per SMACNA & ASHRAE).
- Excessive duct vibration should be explored for root cause of initial duct failure (poorly installed, somebody stepped on it when it was not designed for the load, etc.) or possibly noise transmission from the fan and motor, indicating a problem with the fan/motor assembly – possibly about to fail.
- Check if recent re-model or other work was done in this area (above the drop or hard ceiling). If true it may be prudent to spot check the integrity of various system components after work above ceiling spaces (where ductwork and other building systems are located) has been completed.
- Have systems served by fans with variable frequency drives or inlets vanes (static pressure controlled) encountered changes to static pressures recently (increased static pressure operating set points)? This may contribute to increased leaks or leakage rates.
- The use of a thermal imaging camera (if available) will also help spot air leaks, both in summer (cooling) and winter (heating). Significant temperature contrasts in a thermal image will quickly pinpoint the source of leaks. If a thermal imaging camera is not available, then finding the source of leaks will require more persistence and effort. Professionals rely more and more upon the use of thermal imaging cameras to find these types of problems.

BUILDING WALK-DOWN: AIR DISTRIBUTION SYSTEMS (CONTINUED)

- DUCTWORK THAT IS NOT SEALED CORRECTLY CAN CAUSE THE BUILDING TO BECOME DEPRESSURIZED. THIS CAN ALLOW UNCONDITIONED AND UNFILTERED AIR INTO THE BUILDING LEADING TO HEALTH PROBLEMS FOR THE OCCUPANTS..
- IMPROPERLY SEALED DUCTWORK CAN LEAD TO COMFORT PROBLEMS
- SOMETIMES ONLY MANIFESTED DURING TEMPERATURE EXTREMES THAT ARE AT OR NEAR THE BUILDING DESIGN TEMPERATURES.
- THE POTENTIAL FOR DUCT LEAKAGE CAN BE VALIDATED BY AIR BALANCE EFFORTS THAT DOCUMENT SUPPLY FAN AIR FLOWS (DUCT TRAVERSE READINGS) WHICH SHOULD CLOSELY MATCH THE TOTAL AIR FLOWS MEASURED AT ALL CONNECTED DIFFUSERS (MEASURED WITH A HOOD FLOW APPARATUS).
- UN-INSULATED DUCTWORK IS ALMOST AS BAD AS LEAKY DUCTWORK
  ALTHOUGH THE AIR IS NOT LEAKING, THERE IS SIGNIFICANT HEAT LOSS/GAIN AS THE CONDITIONED AIR FLOWS THROUGH UN-INSULATED DUCTWORK. THIS CAN BE EVEN MORE PRONOUNCED WHEN THE DUCTWORK IS IN ATTIC SPACES OR ON ROOFS, EXPOSED TO HOT OR COLD TEMPERATURES.

11 INVESTIGATION PHASE – BUILDING WALK-DOWN: AIR DISTRIBUTION SYSTEMS

Air Distribution System – prescriptive checks

- The use of a thermal imaging camera (if available) will also help spot air leaks, both in summer (cooling) and winter (heating). Significant temperature contrasts in a thermal image will quickly pinpoint the source of leaks. If a thermal imaging camera is not available, then finding the source of leaks will require more persistence and effort. Professionals rely more and more upon the use of thermal imaging cameras to find these types of problems.
- Consider having a professional perform a duct leakage test. Air leakage rates may increase over time because of: construction (adding to or disturbing the ductwork), damaged ductwork (from maintenance/other activities), exposure to the outdoor elements causing damage to the duct material, operational changes in duct static pressure set points (increased static), etc. A professional can also determine if the duct distribution lines are properly balanced for air flow and design requirements for heating and cooling loads.
- The potential for duct leakage can also be validated by air balance efforts that document supply fan air flows (duct traverse readings) which should closely match the total airflows measured at all connected diffusers (measured with a hood flow apparatus).

Building Walk-down: Air Distribution Systems – What to look for

- Flexible ductwork joints/seams are good candidates for leaks. They are especially susceptible to leaking when located on the outside of a building or exposed to the outdoor elements indirectly.
- Plastic tie bands should be used to reconnect flexible duct to metal collars. Duct tape should only be used for securing insulation to the duct.
- Roof curbs are another area where air can leak. Roof curbs are the stand or mounting that a rooftop unit sits on, when installed on the roof. They are hard to check for leaks, but can be checked by running the fan and feeling around the ductwork for air leaks. The other option is to pull the cover on the unit where the supply and return duct come into the unit, and just reseal with a UL listed ductwork sealer

11 Investigation Phase – Building walk-down: Air Distribution Systems

Air Distribution System – prescriptive checks

- Fan Power design requirements for new offices mandate <1.5 BHP/1000 CFM. Are fans over-sized and creating excess static pressure (or under-sized and not delivering minimum airflows)?
- Are plastic ties used to connect flexible round duct to sheet metal duct? Are they secured or have they come loose? Is “duct” tape used for connecting or sealing leaks?
- Duct sealing requirements are broken into 3 classes (Class C – transverse joints only, Class B – transverse joints and longitudinal seams and Class A – transverse joints, longitudinal seams and all applicable duct penetrations). Depending upon the design class, the effort required (and cost) must be applied to duct sealing in new construction. These classifications determine where sealant must be applied and do not necessarily determine the air leakage rates. Air leakage rates are impacted by construction methods, workmanship, operational fan static pressures, duct design, reheat and variable-air-volume (VAV) boxes and other miscellaneous devices installed in the ductwork.
- ASHRAE 90.1, ASHRAE 189 and IECC should be reviewed for further code information.

Building Walk-down: Air Distribution Systems – What to look For

- Look for insulation that is ballooned when the fan is running, and deflates when the fan goes off. Removal of the insulation to expose the leak may be required.
- Feel for air that is escaping at or around the registers, grills, and vents
- Vents that have no air flow are good candidates for leaking or broken ductwork
- Air movement in attics is also a sign of problems. Is there heated air in the winter and cool air in the summer?
- If attic spaces are adequately insulated, but snow seems to melt quickly from the roof, this is an indicator of heated air getting into the attic that should be further explored.

11 Investigation Phase – Building walk-down: Air Distribution Systems

Air Distribution System – prescriptive checks

- If roofs quickly lose snow and ice or rarely accumulate snow and ice (in climates where snow and ice occur), leaking ductwork above attic spaces should be considered as a possibility (leaking tempered air into the attic space) and investigated.

- If attic spaces or crawl spaces are accessed during cold or hot weather and are found to be "comfortable," it may be due to significant duct leakage. If air movement can be felt in these spaces and they are vented to the outside, check during a non-windy day. If air movement persists, this should be investigated further.

- Are vents in office and similar spaces showing no air flow (or very little)? Verify balancing dampers are not closed or failed closed. If open, and still no air flow, look for leaks in ductwork in the attic or crawl spaces after verifying that the fan delivery systems are working and intact (belts, sheaves, fan and motor assembly working properly, rotating correct direction, etc.).

QUESTIONS?

11 INVESTIGATION PHASE – BUILDING WALK-DOWN: AIR DISTRIBUTION SYSTEMS

- Ask if there are any questions.

Implementation Phase – Introduction

IMPLEMENTATION PHASE: INTRODUCTION

- NOW THAT THE BUILDING WALK-DOWN HAS BEEN COMPLETED, IMPROVEMENT OPPORTUNITIES SHOULD HAVE BEEN IDENTIFIED AND DOCUMENTED
- BASED ON THE FINDINGS FROM THE BUILDING WALK-DOWN, PREPARE AN IMPLEMENTATION PLAN FOR EACH OF THE MAJOR FOCUS AREAS. THE PLAN SHOULD:
  - HIGHLIGHT THE CURRENT CONDITIONS(S) AND PROPOSED CHANGE(S) TO ADDRESS THE CURRENT CONDITION(S) AND POTENTIAL MEASURES THAT CAN BE IMPLEMENTED.
  - INDICATE IF PROPOSED CHANGES REQUIRE ADDITIONAL COST TO IMPLEMENT THE MEASURE.
- THE FOLLOWING SECTIONS WILL PROVIDE THE TRAINER WITH SEVERAL "WHAT'S WRONG" SLIDES THAT PROVIDE STUDENTS THE OPPORTUNITY TO INTERACT WITH THE TRAINING TO COME UP WITH SOLUTIONS TO REAL PROBLEMS, BEGINNING WITH THE BUILDING ENVELOPE.
- THIS IS TIME FOR INTERACTIVE DISCUSSION AND FEEDBACK FROM THE STUDENTS, IF NOT ALREADY OCCURRING.

Chapter 12: Implementation Phase – Building Envelope

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN WHAT PRESCRIPTIVE IMPROVEMENTS TO IMPLEMENT TO THE OUTSIDE OF THE BUILDING

MATERIALS: POWERPOINT SLIDES 12 BUILDING ENVELOPE IMPLEMENTATION PHASE

LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN IMPROVING DOORS AND WINDOWS
- WHAT TO FOCUS ON WHEN IMPROVING WALLS AND ROOFS

12 RE-TUNING STEPS

12 IMPLEMENTATION PHASE – BUILDING ENVELOPE

BUILDING ENVELOPE IMPLEMENTATION: EXTERIOR DOORS – WHAT'S WRONG?

- WHAT SOLUTION DO YOU RECOMMEND?

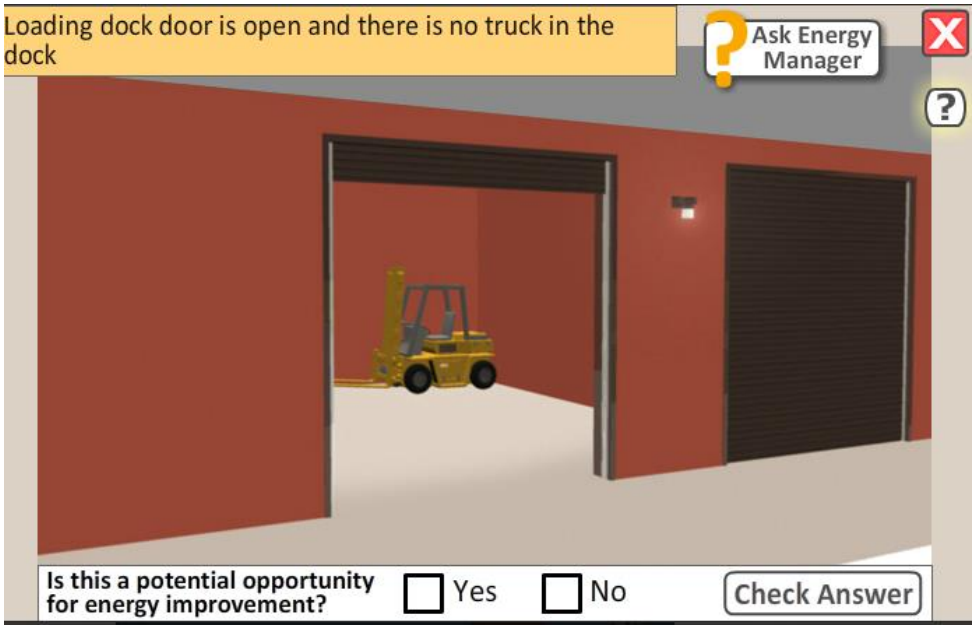
- REMOVE AND REPLACE THE DOOR SEAL WEATHER STRIPPING!

Exterior Doors – implementation suggestions

- Install door seals on exterior doors where non-existent or damaged.
- Install door sweeps on exterior doors where non-existent or damaged.
- Install or adjust door closers on exterior doors for tight closing.
- Replace poorly insulated exterior doors.
- During the building envelope walk-down, what are two things to look for when looking at the doors and windows?
- High traffic doors (lobby entry points, etc.) should be checked more frequently than low-use doors. Doors where material is moved into or out of a building should also be checked more frequently as material being moved often will rub against the doors and damage seals and weather stripping.

BUILDING ENVELOPE IMPLEMENTATION: ROLL-UP DOORS – WHAT'S WRONG?

- WHAT SOLUTION DO YOU RECOMMEND?



- SOLUTION: THE DOOR OPENING CAN BE INTEGRATED TO THE HVAC SYSTEM, SO IF IT IS OPEN FOR MORE THAN A FEW MINUTES, THE HVAC UNIT IS TURNED OFF
- MAKE SURE THE EXTERIOR LIGHTING CONTROL IS WORKING (PHOTOCELL, TIMER, ETC.)

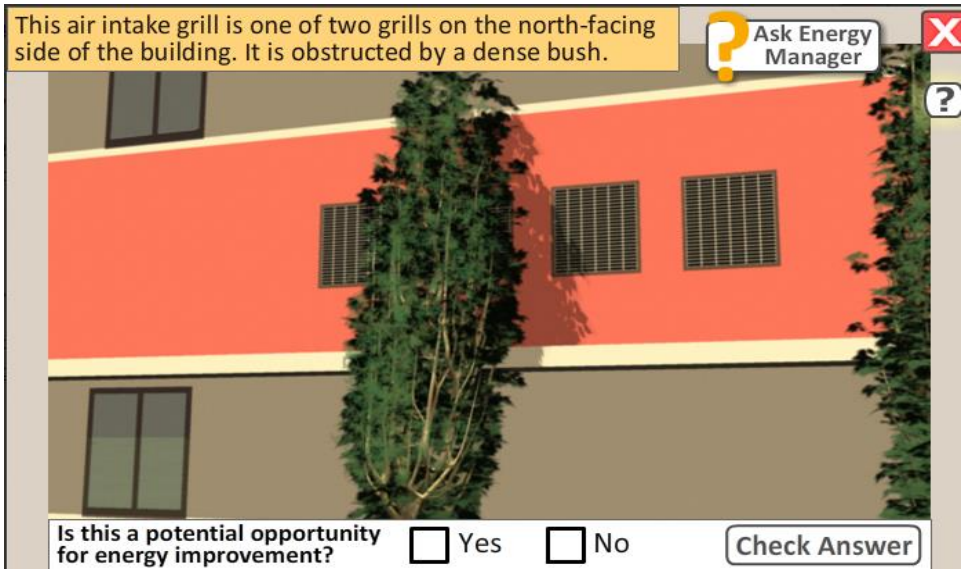
12 IMPLEMENTATION PHASE – BUILDING ENVELOPE

Roll-up Doors – implementation suggestions

- This solution will require some investment in the controls (low-cost). Roll-up door sensors that sense the roll-up door being partially open (more than 1 foot) can be integrated to the HVAC system serving a loading dock or similar warehouse type space. A typical control sequence is to have the sensor turn off the HVAC system if the roll-up door is open for more than 5-15 minutes. A low temperature override should be considered (in case someone leaves the doors open for long periods of time during cold weather). Otherwise, cold air could infiltrate into this space, causing more problems than the energy saved is worth (frozen piping, etc.).
- The outside light is also on. If this were the middle of the day, this may indicate a problem.
- Install door seals on roll-up doors where non-existent or in disrepair.
- Replace poorly insulated roll-up doors.

BUILDING ENVELOPE IMPLEMENTATION: EXTERIOR INTAKE OR EXHAUST GRILLS – WHAT'S WRONG?

- WHAT SOLUTION DO YOU RECOMMEND?



- SOLUTION: TRIM THE BUSHES OR TREES AWAY FROM THE GRILLS

12 IMPLEMENTATION PHASE – BUILDING ENVELOPE

Exterior intake grills – implementation suggestions

- Intake grills do not need potential intake of vegetative debris as this will impede air flow and this can cause problems with HVAC system performance when airflows are decreased.
- Exhaust grills do not need additional obstructions, when trying to exhaust air.

BUILDING ENVELOPE IMPLEMENTATION: EXTERIOR CONDUIT PENETRATION – WHAT'S RIGHT?

- PROPERLY SEALED PENETRATIONS OF ANY PIPING THAT CONVEYS WATER, GAS OR ELECTRICAL SHOULD BE A GOAL FOR ANY BUILDING OWNER OR MAINTENANCE FIRM

- THIS SHOWS CONDUIT SEAL (APPROVED CAULKING SEALANT) APPLIED TO NOT ONLY THE CONDUIT PENETRATION BUT ALSO TO NEARBY SCREW HOLES

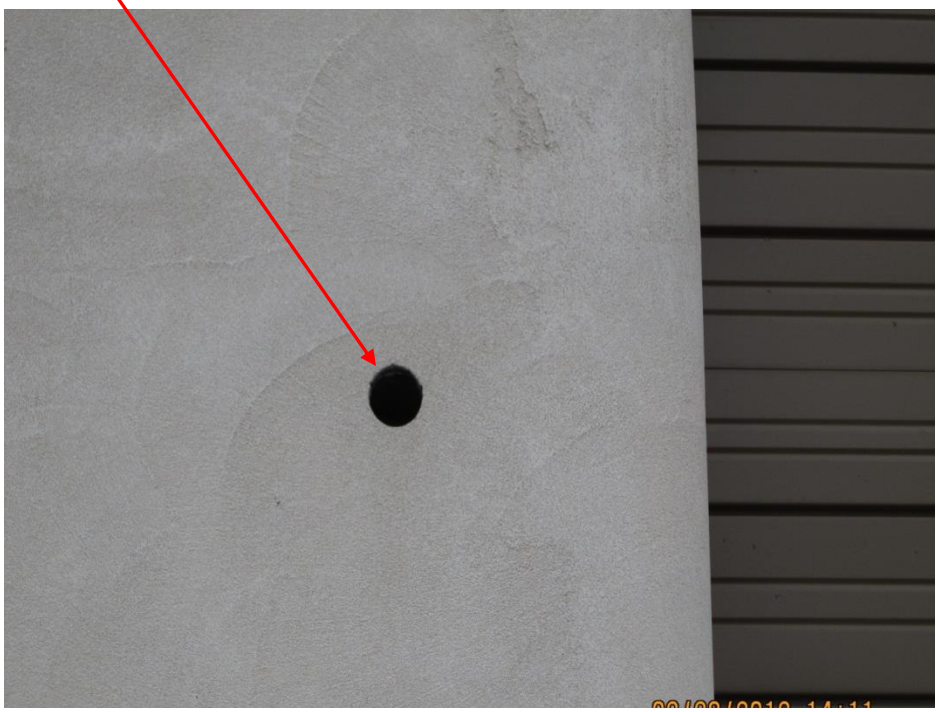
12 IMPLEMENTATION PHASE – BUILDING ENVELOPE

Exterior piping penetrations – implementation suggestions

- A proper caulking, sealing agent rated for exterior use (water and solar resistant) should be used. If an interior wall is being sealed, a fire-rated caulking agent may be required.

BUILDING ENVELOPE IMPLEMENTATION: EXTERIOR PENETRATIONS – HOLES SHOULD BE SEALED

- PENETRATIONS CREATED BY REMOVAL OF PIPING OR OTHER DEVICES THAT WERE MOUNTED TO THE EXTERIOR (OR INTERIOR) OF THE BUILDING SHOULD BE PROPERLY SEALED AFTER THE PIPING OR DEVICE(S) ARE REMOVED



- AN OPENING ALLOWS UNWANTED OUTSIDE AIR, DUST, INSECTS AND POSSIBLY BIRDS OR ANIMALS TO HAVE ACCESS INTO THE BUILDING

12 IMPLEMENTATION PHASE – BUILDING ENVELOPE

Exterior Piping – implementation suggestions

- Hot or cold air infiltration, bugs, dirt and perhaps small rodents may also find access to a building via poorly sealed penetrations.
- A proper caulking, sealing agent rated for exterior use (water and solar resistant) should be used. If an interior wall is being sealed, a fire-rated caulking agent may be required.
- Use paintable sealant for holes in the envelope.

BUILDING ENVELOPE IMPLEMENTATION: EXTERIOR CONDUIT PENETRATION SHOULD BE SEALED

- PENETRATIONS CREATED BY INSTALLATION OF PIPING OR OTHER DEVICES SHOULD BE PROPERLY SEALED AFTER THE PIPING OR DEVICE(S) ARE INSTALLED

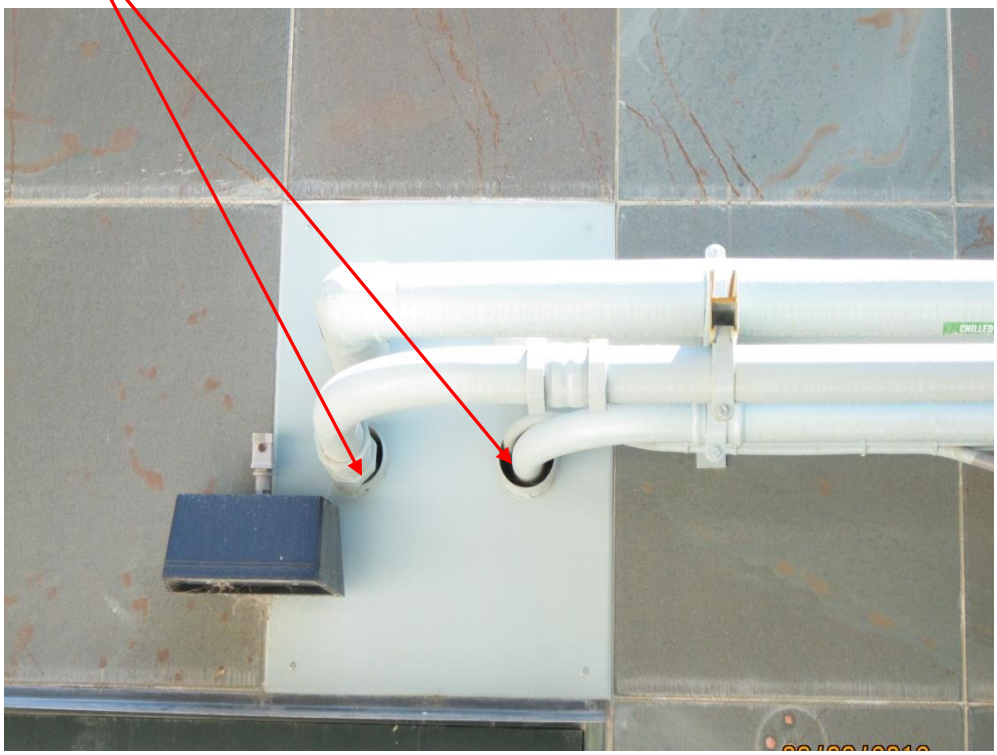
- PIPE CHASES FOR PIPING SHOULD BE SEALED ON THE INSIDE OR OUTSIDE (OR BOTH)

Exterior Piping – implementation suggestions

- Hot or cold air infiltration, bugs, dirt and perhaps small rodents may also find access to a building via poorly sealed penetrations.
- A proper caulking, sealing agent rated for exterior use (water and solar resistant) should be used. If an interior wall is being sealed, a fire-rated caulking agent may be required.
- Use paintable sealant for holes in the envelope.
- Construction activities to make improvements, can often cause envelope problems (insulation removed, not replaced or penetrations created but not sealed properly).

BUILDING ENVELOPE IMPLEMENTATION: EXTERIOR CONDUIT PENETRATIONS SHOULD BE SEALED

- PENETRATIONS CREATED BY INSTALLATION OF PIPING OR OTHER DEVICES SHOULD BE PROPERLY SEALED AFTER THE PIPING OR DEVICE(S) ARE INSTALLED



- PIPE CHASES FOR PIPING SHOULD BE SEALED ON THE INSIDE OR OUTSIDE (OR BOTH)

12 IMPLEMENTATION PHASE – BUILDING ENVELOPE

Exterior Piping – implementation suggestions

- Hot or cold air infiltration, bugs, dirt and perhaps small rodents may also find access to a building via poorly sealed penetrations.
- A proper caulking, sealing agent rated for exterior use (water and solar resistant) should be used. If an interior wall is being sealed, a fire-rated caulking agent may be required.
- Use paintable sealant for holes in the envelope.

BUILDING ENVELOPE IMPLEMENTATION: CLEAN THE ROOF AND PAINT IT WHITE (WHERE APPROPRIATE)

- CLEAN A WHITE ROOF
- IF THE ROOF MATERIAL IS A DARK COLOR, CONSIDER PAINTING IT WHITE

- ARE THE ROOFS CLEAN AND "WHITE?"

Roofs – implementation suggestions

- Check to ensure that the roof surface is clean.
- Even non-white roofs should be free of debris and clean. Debris that collects can also block rain water from draining and this can cause other problems (ponding, etc.) on roofs that can lead to worst problems inside the building.
- An existing roof that is not white can be updated if the right paint material is applied.
- If a contractor is used for this effort, this will not be a "No-Cost" effort.

BUILDING ENVELOPE IMPLEMENTATION: EXTERIOR PLUG LOADS – HEAT TRACE MANAGED PROPERLY?

- TURN THE HEAT TRACE OFF WHEN NOT NEEDED

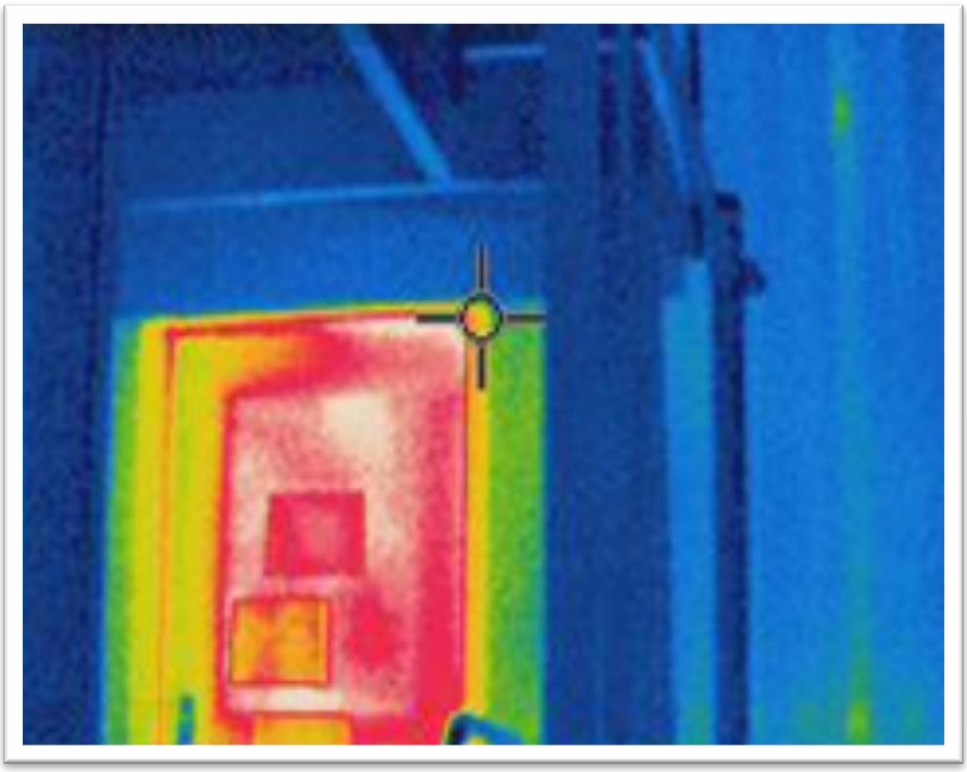
- CONTROL SETTINGS SHOULD BE REVIEWED PERIODICALLY

Heat Trace and other exterior plug loads – implementation suggestions

- Check to ensure that heat trace is off when not needed (seasonally or during mild weather).
- In some cases, it may be easier to manage these loads at the breaker panel or disconnect switch if provided.
- If left on all year, do not assume that because the calendar says “June,”, that they are off (you might be surprised)
- Other exterior plug loads may exist that you are not aware of, without walking the exterior of your building on a periodic basis.
- Other examples can include construction equipment, exterior lighting, signage, etc.

BUILDING ENVELOPE IMPLEMENTATION: EXTERIOR DOORS – WHAT'S WRONG?

- BASED UPON A THERMAL IMAGE OF AN EXTERIOR DOOR, WHAT SOLUTION DO YOU RECOMMEND?



- SOLUTION: EXTERIOR DOORS, WHILE NOT LOW-COST, MAY NEED TO BE REPLACED AND SHOULD BE CONSIDERED WHEN EXISTING DOORS ARE AT THE END OF THEIR USEFUL LIFE AND NEED TO BE REPLACED. ENERGY-EFFICIENT DOORS SHOULD ALWAYS BE CONSIDERED FIRST.

12 IMPLEMENTATION PHASE – BUILDING ENVELOPE

Exterior Doors – implementation suggestions

- Poorly insulated doors may also contribute to entry heaters and air conditioning units running for longer periods of time due to heat gain or heat loss.

BUILDING ENVELOPE IMPLEMENTATION: EXTERIOR WINDOWS – WHAT'S WRONG?

- WHAT SOLUTION DO YOU RECOMMEND?

- SOLUTION: EXTERIOR WINDOWS, WHILE NOT LOW-COST, MAY NEED TO BE REPLACED AND SHOULD BE CONSIDERED WHEN WINDOWS ARE DAMAGED OR AT THE END OF THEIR USEFUL LIFE AND NEED TO BE REPLACED. ENERGY-EFFICIENT WINDOWS SHOULD ALWAYS BE CONSIDERED FIRST.
- THE GLAZING IS CRACKING AND PEELING AND SHOULD BE REPAIRED.

12 IMPLEMENTATION PHASE – BUILDING ENVELOPE

Exterior Windows – implementation suggestions

- Cracked window panes on double or triple-pane windows compromise the thermal barrier.
- The glazing on the edge is cracked and peeling, also an indicator of window compromise.
- Unless qualified for this type of repair, professionals should be hired to ensure a correct window repair/replacement occurs. Otherwise, more problems could be created from improper window repair/replacement.
- A qualified professional will also be able to match the repair/replacement to the existing for U-factor, reflectivity, tinting, thickness, strength, etc.

NOTE: that this is a safety issue (greater reason to replace than just energy improvement) due to potential shards of glass hitting someone.

Building Envelope Walk-Down Exercise

- Exercise

1. During the building envelope walk-down, what are two things to look for when looking at the doors and windows?
2. How do you test to see if heat trace is on in the summer?
3. Which window is the most energy efficient, a single pane or double pane window?
4. True or False: Holes in the building envelope are not cause for concern or worth the effort to seal up properly?
5. View this link to see opportunities that might exist in your home as some or all of these might exist in your building: http://www.energystar.gov/ia/partners/publications/pubdocs/Seal_and_Insulate.pdf?e1c6b233

12 Implementation Phase – Building Envelope

Exterior Windows – implementation suggestions

1. Doors should be checked for proper seals along tops, sides and bottoms. Windows should be checked for cracks, caulking and if operable – that they are closed.
2. Check with a temperature gun or your hand (warmer than ambient to the touch).
3. Double Pane
4. False

Chapter 13: Implementation Phase – HVAC Systems and Controls

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN WHAT PRESCRIPTIVE IMPROVEMENTS TO IMPLEMENT ON THE HVAC SYSTEMS OF THE BUILDING

MATERIALS: POWERPOINT SLIDES 13 BUILDING HVAC SYSTEMS IMPLEMENTATION PHASE

LEARNING OBJECTIVES:

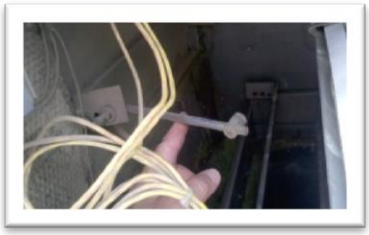
- WHAT TO FOCUS ON WHEN IMPROVING HVAC RTUS
- WHAT TO FOCUS ON WHEN IMPROVING HVAC CONTROLS

13 RE-TUNING STEPS

13 IMPLEMENTATION PHASE – HVAC SYSTEMS AND CONTROLS

BUILDING HVAC SYSTEMS IMPLEMENTATION: HVAC ECONOMIZERS LACK OF MAINTENANCE

- ENSURE THAT LINKAGES, ACTUATORS, DAMPER BLADES AND CONTROLS ARE WORKING CORRECTLY



13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Economizers – implementation suggestions:

- Tighten loose linkages and lubricate damper shafts so dampers move freely.
- Adjust economizer controller for correct set point setting per vendor installation and startup literature and matched to local climate zone (if enthalpy is used). Otherwise, suggest dry bulb setting of 70°F for western U.S. and 65°F for mid-west and northeast U.S. and 60°F for southeast U.S.
- If Demand Control Ventilation (DCV) is part of economizer controls, the CO_2 sensor should be verified for correct reading and the minimum to maximum damper response when the CO_2 sensor is below allowed limit and exceeds maximum limit should be verified. The recommended minimum damper response is 0-5% open and the maximum limit should not be greater than the current minimum damper response without CO_2 (DCV) control. Most office buildings usually have minimum damper positions in the range of 10-30% open, but this can vary based upon many factors.
- Verify that the dampers are properly set at their minimum position. Calculate the outdoor air fraction by reading the return-air temperature (RAT), mixed-air temperature (RAT) and outdoor-air temperature (OAT). The equation for this is as follows: [(RAT-MAT) / (RAT-OAT)] * 100. For example, if the temperatures recorded are: RAT = 72, MAT = 60 & OAT = 40, the equation would be [(72-60) / (72-40)] * 100 = [12/32] * 100 = 37.5% open. Normally, minimum damper settings would not be more than 10-20% open. This might indicate a system that is over-ventilating when the damper is at its minimum setting and in need of some adjustment.
- If DCV does not exist, this may be one opportunity to consider for possible improvement (unless the existing thermostat or digital controls already have this capability incorporated in the controls). DCV (depending upon the design requirements required by local energy codes) allows for using one or more sensors to measure CO_2 in the space being ventilated. Based upon the measured readings (Parts Per Million – PPM), and the required minimum or required difference when compared to some known outside ambient value, the outside air dampers may be allowed to remain closed or mostly closed as compared to standard ventilation controls.

BUILDING HVAC SYSTEMS IMPLEMENTATION: HVAC LOUVERS AND GRILLS PERFORMANCE

- FIX LOUVERS THAT DO NOT OPEN PROPERLY
- CLEAN GRILLS THAT ARE DIRTY

13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Economizers – implementation suggestions:

- The picture on the left shows the power exhaust fan relieving building air out the roof top unit's power exhaust fan's back draft damper. When the power exhaust fan is not running, the back draft damper should close adequately to mitigate excess outside air being drawn into the rooftop unit during cold or hot weather. If it does not close, make adjustments to the louver by lubricating the hinges or clearing obstructions to ensure that it closes when the power exhaust fan is not running.
- Verify that the power exhaust fan does not run until the economizer outside air damper is at least 50% open (or greater). If the economizer damper is mostly closed and the power exhaust fan is running, this can lead to the building space experiencing a negative static pressure condition, which will result in outside air infiltrating into the building space (not desired).
- Keep intake screens clear of vegetation and debris.
- Look at the economizer intake bird screens. They are sometimes low to the roof structure (or ground if located on the ground) and hard to remove. Generally the intake screens never get checked or cleaned during maintenance if the packaged units have economizers.
- Clean dirty intake screens (usually with water or compressed air).

BUILDING HVAC SYSTEMS IMPLEMENTATION: HVAC LOUVERS AND GRILLS PERFORMANCE

- CLEAN INTAKE SCREENS ON ROOFTOP EQUIPMENT BEFORE THEY BECOME PLUGGED

13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Economizers – implementation suggestions:

- The picture above shows a clogged intake screen. This Rooftop Unit was unable to economize properly, resulting in mechanical cooling required to operate sooner than it should have.
- This was also contributing to a negative building condition (unable to draw outside air in for adequate ventilation and pressurization). This may cause comfort problems in the spaces during hot and cold weather.
- These intake screens can often be overlooked by maintenance staff as they are sometimes "out-of-sight, out-of-mind."
- These screens should be periodically inspected (prior to the cooling and heating seasons – spring and fall) and cleaned before accumulations exceed the point of being able to see light through the screens.

BUILDING HVAC SYSTEMS IMPLEMENTATION: GENERAL GUIDANCE

- HEATING AND COOLING SYSTEMS
- NOISES, SMELLS, BELTS, BEARINGS, SHEAVES
- HEAT PUMP CYCLES
- POWER

13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Systems general guidelines – implementation suggestions:

- Inspect and verify that the disconnect is turned on all HVAC systems (many times they are not – leading to occupant comfort issues and use of other (portable heaters, fans, etc) to solve comfort.
- Listen for loud noises and feel for unusual vibrations and smell for any signs of burning. Identify sources and resolve or notify others for further resolution.
- Fix or replace loose fan belts (motor running without belts happens a lot!).
- Inspect and adjust sheaves for proper fan operation, lubricate bearings as required.
- Clean dirty fan wheels and dirty coils and change dirty filters.
- Clean condensate drain pan and ensure trap is primed prior to the cooling season.
- Secure equipment cabinet doors and panels that are loose (keep the outside air from entering into the building, except through the outside air intake filtration system).
- Inspect heat pump defrost cycles for correct operations, especially during moist weather when outdoor-air temperatures are below 40^{o}F that persist for several days. If outdoor coils do not defrost properly, the heat pump cannot work properly.
- Verify that the heat pump control for the auxiliary heating coil (gas or electric as designed) is configured correctly when outside air temperatures drop below minimum design conditions.

- Inspect for signs of Freon leakage on the outdoor and indoor coils (oil will accumulate and dirt will collect at that location in large quantities) and repair or notify others for future repair.
- Inspect for missing insulation and replace or loose duct connections and secure correctly.
- Remove legacy systems.

BUILDING HVAC SYSTEMS IMPLEMENTATION: HVAC ECONOMIZER COMPONENT – WHAT'S WRONG?

- YOU FIND THE OUTDOOR AIR DAMPER HAS A BROKEN LINKAGE. WHAT SOLUTION DO YOU RECOMMEND?

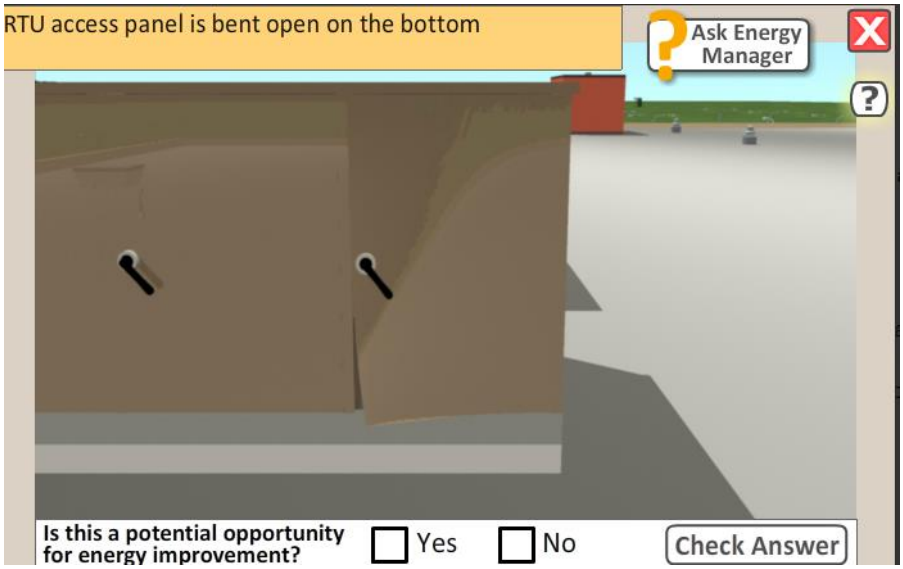
- SOLUTION: FIX THE LINKAGE AND MAKE SURE THE ECONOMIZER IS OPERATING CORRECTLY AFTER THE REPAIR!

HVAC Economizers – implementation suggestions:

- It is also possible that the damper was disconnected on purpose by the service provider or maintenance organization as the economizer controller or actuator may have failed with the outdoor dampers in a mostly open (energy intensive) position.
- Verify that, before you reconnect, the economizer controller and actuator are working correctly. If not, replacement may be necessary.

BUILDING HVAC SYSTEMS IMPLEMENTATION: HVAC SYSTEM – WHAT'S WRONG?

- YOU FIND ROOF TOP UNIT HAS A BENT ACCESS PANEL. WHAT SOLUTION DO YOU RECOMMEND?



- SOLUTION: FIX THE BENT ACCESS PANEL DOOR TO MITIGATE LEAKAGE OF OUTSIDE AIR INTO THE UNIT

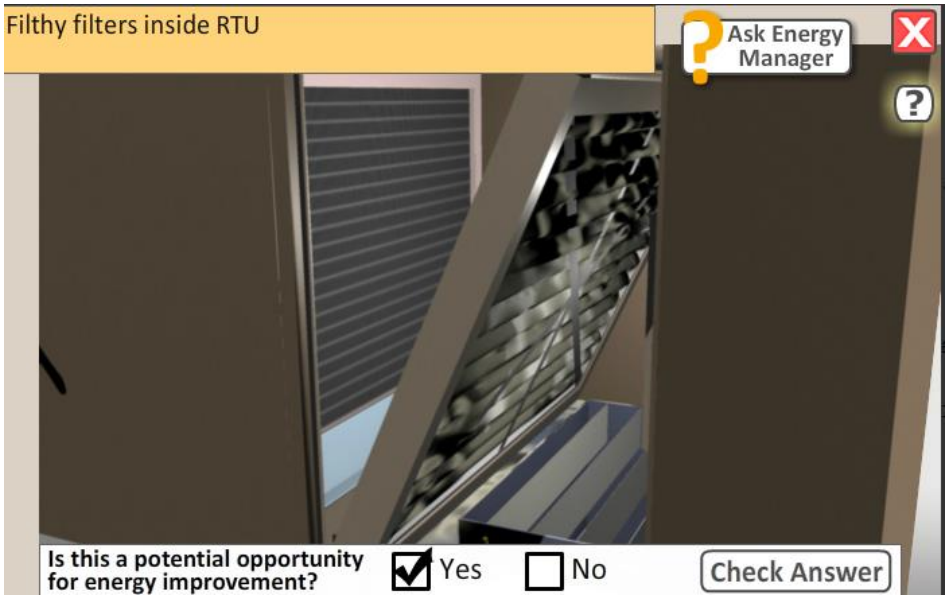
13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Roof Top Units – implementation suggestions:

- When duct leakage is being evaluated, it is important to also consider HVAC components and accessories (as noted in the slide) as extensions or duct devices that can contribute to air leakage and sometimes in more significant ways than the actual ducts.
- These HVAC systems are easier to access than ducts, so their proper configuration is something that should be given attention to.

BUILDING HVAC SYSTEMS IMPLEMENTATION: HVAC SYSTEM – WHAT'S WRONG?

- YOU FIND ROOF TOP UNIT HAS DIRTY FILTERS. WHAT SOLUTION DO YOU RECOMMEND?



- SOLUTION: REPLACE THE DIRTY FILTERS BEFORE THEY CLOG OR START PASSING DIRTY AIR TO THE HEATING AND COOLING COILS AND FAN SECTION, AND CONSEQUENTLY INTO THE BUILDING SPACES

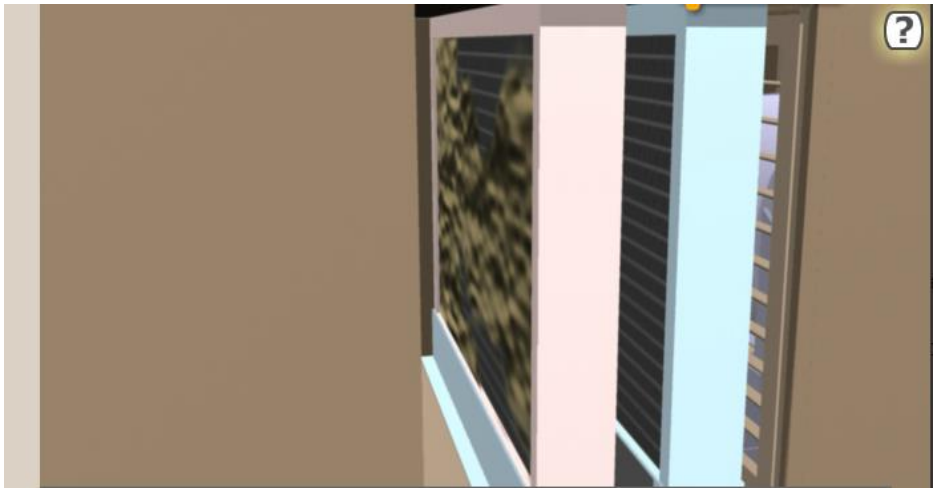
13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Roof Top Units – implementation suggestions:

- Make sure the correct filters (size, minimum ratings etc.) are always used.
- If the unit comes with filter racks and filter seal plates, make sure they are installed (so air cannot bypass around the filters).
- Filters should be dated (so the next person knows when they were installed) when replaces and installed with arrows in the correct direction of air flow.

BUILDING HVAC SYSTEMS IMPLEMENTATION: HVAC SYSTEM – WHAT'S WRONG?

- YOU FIND ROOF TOP UNIT HAS DIRTY COILS. WHAT SOLUTION DO YOU RECOMMEND?



- SOLUTION: CLEAN THE DIRTY COILS BEFORE THEY CLOG AND IMPACT AIR DELIVERY AND COMFORT AND POSSIBLE EQUIPMENT DAMAGE (COMPRESSORS, ETC.).

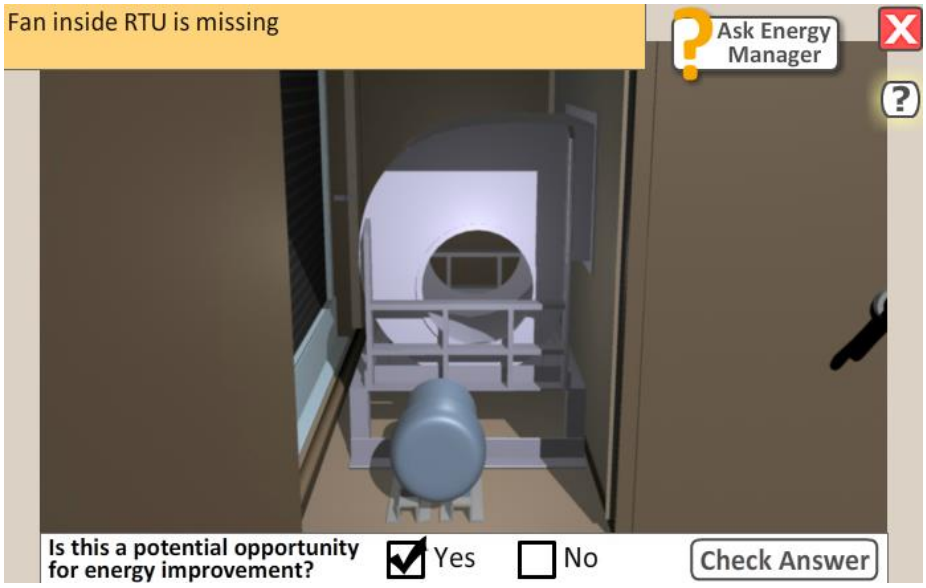
13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Roof Top Units – implementation suggestions:

- Care with coil fins should always be exercised when cleaning coils. If the fins are bent over, they will impede air flow, create added restrictions and negatively impact heat transfer to the coils.
- Dirty coils can also affect air flow, which can affect compressor performance. If air flow is too low, the evaporator coil can start to freeze. If this occurs, it is possible for refrigerant to flood back to the compressor as a liquid, potentially damaging the compressor (especially on older compressors that are not as kind with liquid).
- Use a recommended cleaning agent to remove dirt and grease.

BUILDING HVAC SYSTEMS IMPLEMENTATION: HVAC SYSTEM – WHAT'S WRONG?

- YOU FIND ROOF TOP UNIT FAN IS MISSING. WHAT SOLUTION DO YOU RECOMMEND?



- SOLUTION: REPORT THAT PROBLEM TO THE OWNER – THIS WILL REQUIRE CAPITAL TO FIX (INSTALL A NEW MOTOR).

HVAC Roof Top Units – implementation suggestions:

- When some RTUs have failed, the other RTUs adjacent to the space served by the failed units may have to work harder, as those adjacent spaces will impact the working RTUs during hot or cold weather.
- This is due to their proximity and O&M staff leaving doors open to allow spaces served by working RTUs to "spill" their conditioned air to help offset the heating and cooling loads that are no longer being served. So this condition can cause cascading problems to other HVAC systems, if not resolved.

BUILDING HVAC SYSTEMS IMPLEMENTATION: HVAC SYSTEM – WHAT'S WRONG?

- YOU FIND ROOF TOP UNIT FAN IS MAKING A VERY LOUD NOISE. WHAT SOLUTION DO YOU RECOMMEND?

- SOLUTION: REPORT THAT PROBLEM TO THE OWNER – THIS MAY REQUIRE CAPITAL TO FIX (INSTALL A NEW FAN AND MOTOR ASSEMBLY).

13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Roof Top Units – implementation suggestions:

- This probably is more of a maintenance issue, but if the belts are not properly installed or more energy-efficient belts (application dependent) were not installed, this may be an energy efficiency improvement opportunity for the maintenance team.
- When belts are not aligned properly between the motor and fan, it is possible to generate excessive friction, torque and strain on several components above. This can include the belts, the motor, the motor bearings and even the fan shaft. If this results in additional frictional losses, these can reduce the motor efficiency (increased motor load) by 5-10%.

BUILDING HVAC SYSTEMS IMPLEMENTATION: DIFFERENT HVAC SYSTEMS GENERAL GUIDANCE

- SOME PACKAGED EQUIPMENT WILL HAVE GAS-FIRED HEATING SYSTEMS (NOT ELECTRIC)
  - VERIFY THAT THE COMBUSTION-AIR INTAKE IS PROPERLY CONFIGURED W/NO BLOCKAGE
  - VERIFY THAT THE GAS PRESSURE REGULATOR IS SET CORRECTLY (TRAINED TECHNICIAN)

- THESE (3) PICTURES REPRESENT DIFFERENT HVAC SYSTEMS ON ROOFS THAT ARE PROBABLY STILL IN OPERATION TODAY. THEY INDICATE THE COMPLEXITY OF POOR DESIGN AND LACK OF MAINTENANCE.

HVAC Systems general guidelines – more implementation suggestions:

- Look for abandoned equipment that is no longer in use. In many cases this old equipment gets no attention and can be a place where energy is wasted unknowingly by allowing air to infiltrate the building, which can cause comfort issues and raise the cost of heating and cooling a building.
- Walk around all of the equipment, noting the model numbers and serial number. If replacement parts or manuals are needed this will be important to have to find correct components.
- Make some general notes about the condition of the equipment. Examples (Clean or dirty coils and intake grills, panels or parts missing, panels that are bent, ill-fitting or missing screws)
- Are there any uncommon noises (thumps, squeaks or vibrations) coming from the equipment?
- Note all the different types of equipment (Conditioning - Gas Packaged or Heat Pump, Non-conditioning - intakes and exhausts).

- Look at exposed ductwork, looking for air leaks and holes in the sheet metal. Missing seals where the ductwork matches up to the unit or leaks at other connections and roof curbs.

- Turn the unit off (**Stress safety before proceeding beyond this point!**) and follow required safety procedures (Lock & Tag, etc.).

- Open up the covers on the unit and look at the filter and coils. Make sure the filters are the correct size and there is no area for air to bypass around the filter. Pull out a filter to see how dirty the filter is, or when it was last changed. Verify the filter is installed correctly regarding the proper direction of airflow through the filter. While the filter is removed, look at the cooling coil. It should be clean and free of debris. Look at the drain pan under the cooling coil. It should be somewhat clean and have no standing water in it. If there is standing water in the pan, the trap may be plugged or installed incorrectly, or the unit does not have a trap installed. If the unit has a trap on outlet of the drain pan, check to see if it has water in it. If the filters and coils are clean there is a pretty good chance that the units are receiving regular maintenance.

- Look at the fan. Is the blower wheel and motor clean? If there is a fan belt, are the sheaves in good shape? They should not be grooved out too deeply. Is the fan belt in good condition? Verify that it is not cracked or broken.

- Is the refrigeration system properly charged (**with safety in mind as this is a pressurized system that only trained and qualified personnel should work on beyond this point**)? This is generally verified as part of the scheduled maintenance service. If you are not qualified to check the refrigerant charge, it is a good idea to have someone who knows how to do this for a few reasons. The first reason is safety, the second reason is that if not done properly, problems within the refrigeration system can be created that can lead to high energy and maintenance costs and the third reason is that many parts of the country will fine workers not qualified to work around refrigerants (ODS – Ozone Depleting Substances). More than likely there will be some comfort issues before the problems are fixed. For the building walk-down, look around the refrigeration system for any places with a lot of oil that is dripping or coating an item on the refrigeration system. This may be a location for a possible refrigerant leak. It could also be a sign that the system maybe undercharged. An undercharged system will run longer to satisfy the load then is needed. It will also shorten the life of the compressor.

- Places to look for a refrigerant leak are the coils, the copper piping that connects to the coils, and the compressor. Any item that is in the refrigeration system can develop a leak. If a leak is developed over time it will grow bigger over time. Maintenance companies are required to keep records of where they sell or install refrigerant for the EPA. It may be possible to find out if there is a unit that is always in need of additional refrigerant periodically throughout the year.

- Look for an outdoor lockout thermostat that is wired to the second stage heating (electric heater) on a heat pump. The thermostat should be a set to a temperature at which the heat pump is no longer efficient and the electric heat needs to be the primary source of heat.

Depending on the geographic location and the SEER (**S**easonal **E**nergy **E**fficiency **R**atio) rating, these factors will decide what that set point should be. We look for this to insure that the second stage of heat does not come on with a first stage of heat every time there is a call for heat. Back to the SEER rating, the higher the rating the more efficient the unit. SEER ratings are calculated by dividing the amount of cooling supplied by the air conditioner or heat pump (BTU's per hour) by the power (Watts) used by the cooling equipment under a specific set of seasonal conditions.

BUILDING HVAC SYSTEMS IMPLEMENTATION: THERMOSTATS – WHAT'S WRONG?

- WHAT'S WRONG WITH THESE PICTURES? WHAT SOLUTION DO YOU RECOMMEND?

- EITHER RELOCATE THE THERMOSTAT OR MOVE THE OFFICE EQUIPMENT THAT IS GENERATING HEAT

HVAC Thermostats – implementation suggestions:

- Besides unwanted sources of heat from office equipment, thermostats can also be impacted by direct sunlight coming through windows (solar gain) or from direct impact from diffusers that "throw" air directly on the thermostat.
- Thermostats can be found on perimeter walls or support columns near perimeter windows. These locations often are impacted by outside temperature conditions and can cause conflicted thermostat control.
- Thermostats located on walls that separate two different zones, can be impacted by the adjacent zone. Interior walls are rarely insulated and if the temperature in the adjacent zone is significantly different (delta T > 8^{o}F, this can result in energy flow between zones.
- Just like a realtor will tell a prospective home buyer……."LOCATION, LOCATION, LOCATION!"
- Location is important for your house and it's important for the HVAC system's thermostat!
- Verify the location of existing thermostats (or when preparing to install new thermostats) is the optimum location for the space and HVAC system it serves.
- If the thermostat is mechanical, replacing it with a digital thermostat will save money (if properly configured). If the mechanical thermostat is left in place, ensure it is configured for acceptable set points.

BUILDING HVAC SYSTEMS IMPLEMENTATION: PROGRAMMABLE THERMOSTAT SET POINT SCENARIO

- THE BUILDING HAS A PROGRAMMABLE THERMOSTAT, BUT IT IS NOT PROGRAMMED TO TAKE ADVANTAGE OF UNOCCUPIED SETBACKS AND SET UPS
- WHAT WOULD YOU RECOMMEND?
- PROGRAM THE THERMOSTAT AS FOLLOWS:
  - UNOCCUPIED HEATING SET POINT = 65°F
  - OCCUPIED HEATING SET POINT = 72°F
  - OCCUPIED COOLING SET POINT = 75°F
  - UNOCCUPIED COOLING SET POINT = 82°F

13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Thermostats – implementation suggestions:

- Configure programmable thermostats properly for set points and schedules that match occupancy schedules of the building or zone served.
- The example above shows the difference between the occupied heating and occupied cooling set points to be at least 3°F. This difference (a.k.a. "Range" or "Dead Band") should be wider (the wider, the greater the energy savings) during the unoccupied period. In the example above, the unoccupied difference is 17°F.
- **Why do scheduled settings in programmable thermostats degrade (widen) over time (energy savings persistence is lost)**? Here are some possible reasons, that one should be aware of and consider what new technology in the market place (or existing features in existing thermostats) may help to mitigate:
  - Extreme weather (**Solution** – Optimal Start Feature)
  - Mission or space changes where RTU serves multiple office spaces (**Solution** – wired or wireless temperature sensors)
  - Temporary schedule changes (**Solution** – temporary occupancy override button)
  - Unplanned use events (**Solution** – temporary occupancy override button)
  - Other (Verify location and false readings are not impacting thermostat response) – Thermostats in vacant, locked office spaces are very problematic
- Configure programmable thermostat's optimal start program (if it exists)
- Verify that the thermostat is not in "Hold" mode (Override)
- View this link to see a demonstration of setting up a programmable thermostat's functions: http://www.energystar.gov/index.cfm?fuseaction=vid_gallery.showGenYTVideo

BUILDING HVAC SYSTEMS IMPLEMENTATION: PROGRAMMABLE THERMOSTAT SCHEDULE SCENARIO

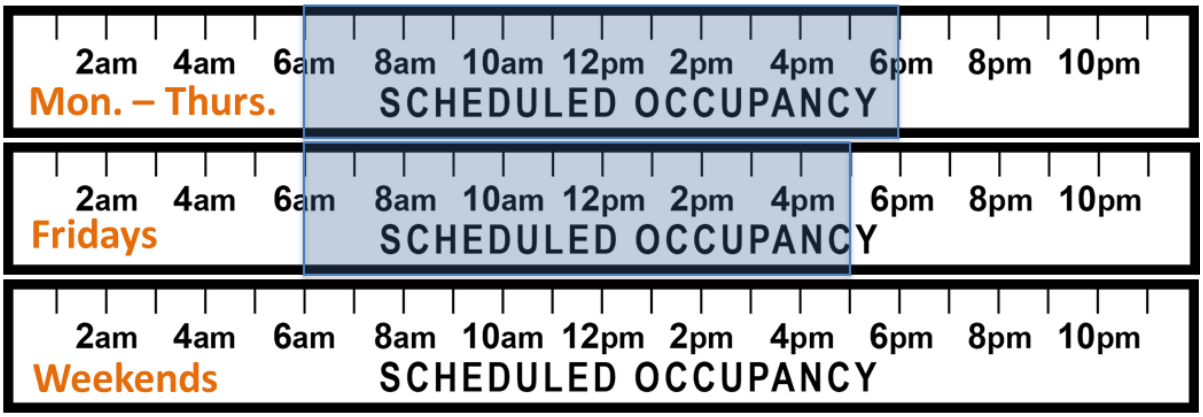
- THE BUILDING HAS A PROGRAMMABLE THERMOSTAT, BUT IT IS NOT PROGRAMMED TO TAKE ADVANTAGE OF SCHEDULES – IT CAN BE PROGRAMMED BY DAY OF THE WEEK
- WHAT WOULD YOU RECOMMEND?
- TALK TO THE BUILDING OCCUPANTS/OWNER/MANAGER AND FIGURE OUT WHAT THE TYPICAL OCCUPANCY IS FOR EACH DAY OF THE WEEK
- BASED ON DISCUSSION WITH BUILDING OCCUPANTS THE BUILDING IS TYPICALLY:
  - OCCUPIED FROM 7:30 A.M. TO 6:00 P.M. ON MONDAY THRU THURSDAY
  - FROM 7:30 A.M. TO 5:00 P.M. ON FRIDAY'S
- NO OCCUPANCY ON WEEKENDS

HVAC Thermostats – implementation suggestions:

- Configure programmable thermostats properly for set points and schedules that match occupancy schedules of the building or zone served.
- **Why do scheduled settings in programmable thermostats degrade (widen) over time (energy savings persistence is lost)**? Here are some possible reasons, that one should be aware of and consider what new technology in the market place (or existing features in existing thermostats) may help to mitigate:
  - Extreme weather (**Solution** – Optimal Start Feature)
  - Mission or space changes where RTU serves multiple office spaces (**Solution** – wired or wireless temperature sensors)
  - Temporary schedule changes (**Solution** – temporary occupancy override button)
  - Unplanned use events (**Solution** – temporary occupancy override button)
  - Other (Verify location and false readings are not impacting thermostat response) – Thermostats in vacant, locked office spaces are very problematic
- Configure programmable thermostat's optimal start program (if it exists)
- Verify that the thermostat is not in "Hold" mode (Override)
- View this link to see a demonstration of setting up a programmable thermostat's functions: http://www.energystar.gov/index.cfm?fuseaction=vid_gallery.showGenYTVideo

BUILDING HVAC SYSTEMS IMPLEMENTATION: PROGRAMMABLE THERMOSTAT SCHEDULE SCENARIO

- PROGRAM THE SCHEDULES IN THE THERMOSTAT AS FOLLOWS:
  - MONDAY - THURSDAY OCCUPIED FROM 6:00 A.M. TO 6:00 P.M.
  - FRIDAY OCCUPIED FROM 6:00 A.M. TO 5:00 P.M.
  - SATURDAY-SUNDAY UNOCCUPIED FROM 12:00 A.M. TO 11:59 P.M.
- IF THE THERMOSTAT HAS AN OPTIMAL START CAPABILITY, THEN THE START TIMES CAN BE CONFIGURED FOR LATER THAN 6:00 A.M. FOR EXAMPLE, IT CAN BE 7:30 A.M. AND THE OPTIMAL START PROGRAM WILL ACCOUNT FOR EARLIER STARTS



13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Thermostats – implementation suggestions:

- Configure programmable thermostats properly for set points and schedules that match occupancy schedules of building or zone served
- Based upon the discussion with building owners and occupants, the actual hours of occupancy begin at 7:30 a.m. This means that with optimal start, the start times can be as late as 7:00 a.m. (allows 30 minutes to purge stale air from the building prior to occupancy).
- Since Monday comes after a 2-day weekend, it may be advisable to set Monday's start time to be one hour earlier (recovery issues). Otherwise, occupant complaints could result in the entire schedule being pushed back to 5 a.m., for every day (out of frustration).

BUILDING HVAC SYSTEMS IMPLEMENTATION: PROGRAMMABLE THERMOSTAT SCHEDULE SCENARIO FOR HEAT PUMPS

- IF THE BUILDING HAS PACKAGED HEAT PUMPS WITH AUXILIARY ELECTRIC HEAT, SETBACKS CAN INCREASE A BUILDING'S ELECTRIC DEMAND SIGNIFICANTLY DURING MORNING WARM UP PERIOD AS THE SPACE WARMS FROM UNOCCUPIED TO OCCUPIED SET POINTS
- CHECK TO SEE IF THE PACKAGED HEAT PUMP COMES WITH AN INDEPENDENT OUTDOOR AIR TEMPERATURE LOCKOUT FOR THE AUXILLARY ELECTRIC HEAT (SOME DO, SOME DO NOT). IF PROVIDED, ENSURE THAT THE LOCKOUT IS SET AT THE LOWEST POSSIBLE OUTDOOR TEMPERATURE SETTING. MOST LOCAL UTILITIES CAN ADVISE ON THIS SETTING
- IF THE PACKAGED HEAT PUMP DOES NOT HAVE AN INDEPENDENT OUTDOOR AIR TEMPERATURE LOCKOUT FOR AUXILLARY ELECTRIC HEAT, THE PROGRAMMABLE THERMOSTAT MAY HAVE THIS CAPABILITY (AUXILLARY HEAT OUTDOOR LOCKOUT). IF IT DOES, USE IT
- IF IT DOES NOT, SEE IF THE THERMOSTAT HAS MULTIPLE SCHEDULING OF SET POINTS CAPABILITY. IF THE THERMOSTAT HAS MULTIPLE SCHEDULES, CONSIDER RAISING THE SET POINT IN 2 DEGREE F INCREMENTS STARTING AT 5 A.M., 6 A.M. AND 7 A.M.
- "SMART" THERMOSTATS DESIGNED FOR HEAT PUMPS, AUTOMATICALLY PERFORM THE PREVIOUS FUNCTION WITHOUT ANY ADDITIONAL SCHEDULING (INTELLIGENT RECOVERY)

13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Thermostats – implementation suggestions:

- If the setback value is 65°F (beginning at 6 PM the week night before or the Friday night before the weekend), the following morning with a scheduled work occupancy should use the power of the thermostat's multiple schedules to increment the heating set point by 2°F every hour, starting at 5 am. The following is a typical schedule:
    - 65°F unoccupied heating set point at night and during the weekend
    - 5:00 am 67°F occupied heating set point
    - 6:00 am 69°F occupied heating set point
    - 7:00 am 71°F occupied heating set point
    - 8:00 am 72°F occupied heating set point (final value)
    - 5:00 pm (Friday) or 6:00 pm (Monday – Thursday) 65°F unoccupied heating set point

- This is possible with a thermostat that provides for 5 schedules per day and is a valid use. If the thermostat is only increasing 2°F in each step, the electric auxillary heating should not be used (or minimally used). If the thermostat has a dead band value to preclude use of electric heat, it should be set for 2°F.

- Also check to see if the heat pump has an outdoor lock out thermostat for the second stage electric (auxillary) heat. This should be set as low as possible (consult with the heat pump vendor and their recommendation for the geographical location and the heat pump's SEER rating, etc.).

- These are some recommended steps for mitigating electric demand spikes on the building's electric meter, during morning warm up periods.

BUILDING HVAC SYSTEMS IMPLEMENTATION: PROGRAMMABLE THERMOSTAT SET POINT SCENARIO

- IF THE DIFFERENCE BETWEEN HEATING AND COOLING SET POINT IS LOW, FOR EXAMPLE, 1°F, WHAT SHOULD YOU DO?
  - HEATING SET POINT - 73°F
  - COOLING SET POINT - 74°F

- CHANGE THE SET POINTS TO:
  - HEATING SET POINT - 72°F (OR LOWER)
  - COOLING SET POINT - 75°F (OR HIGHER)

13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Thermostats – implementation suggestions:

- Every 1°F dead band increase can result in as much as 1% energy savings.
- Tight set points can result in equipment cycling between heating and cooling (especially if the equipment is oversized, or the loads are reduced – nights and weekends).
- ASHRAE now recommends 5°F for minimum dead band values

BUILDING HVAC SYSTEMS IMPLEMENTATION: PROGRAMMABLE THERMOSTAT FAN OPERATION SCENARIO

- THE PROGRAMMABLE THERMOSTAT IS SET TO "AUTO FAN," WHICH MEANS THE FAN WILL CYCLE ON/OFF WITH THE COOLING OR HEATING COMMANDS.
- IS THIS AN ACCEPTABLE PRACTICE?
- PROBABLY NOT! BECAUSE IT MAY NOT MEET THE VENTILATION CODE REQUIREMENTS
- SUGGEST CHANGING THE SETTING TO "FAN-ON" WHEN THE THERMOSTAT IS IN THE "OCCUPIED" MODE
- MOST PROGRAMMABLE THERMOSTATS SUPPORT THIS CONFIGURATION
- THIS WILL INCREASE YOUR ELECTRICITY CONSUMPTION, BUT MAY ALSO IMPROVE COMFORT AND MEET THE VENTILATION CODE REQUIREMENTS
- PUTTING YOUR THERMOSTAT IN A "HOLD" MODE MAY ALSO INCREASE ENERGY CONSUMPTION NEEDLESSLY BY ALWAYS "HOLDING" THE SET POINT AND NOT RELEASING TO UNOCCUPIED SETTINGS

HVAC Thermostats – implementation suggestions:

- There are now products on the market, to reduce fan power (VFD controlled) that respond to thermostat signals. When there is no call for heating or cooling, the VFD automatically reduces speed by as much as 50%. Fan energy savings can be significant. Adding this capability is probably a capital improvement effort with a very quick payback.
- A relatively new feature for the commercial market is called the "Stir" feature. It is for the "occupied mode" when thermostats are not configured for continuous run mode is designed to mitigate "stratification" and to help improve ventilation rates.

BUILDING HVAC SYSTEMS IMPLEMENTATION: EXHAUST FANS SCENARIO

- THE BUILDING HAS A LARGE NUMBER OF EXHAUST FANS THAT ARE RUNNING ALL DAY (24X7)
- WHAT CAN WE DO?
- IF THE EXHAUST FANS HAVE TIME CLOCKS, PROGRAM THEM TO OPERATE ONLY WHEN NEEDED – WHEN THE BUILDING IS OCCUPIED
- IF THE EXHAUST FANS DO NOT HAVE TIME CLOCKS, THEN RECOMMEND TO THE BUILDING OWNER TO ADD TIME CLOCKS
- IF THE THERMOSTAT HAS AN AUXILIARY OUTPUT FOR EXHAUST FANS AND THEY SERVE SIMILAR AREAS, CONSIDER USING THE THERMOSTAT TO CONTROL THOSE EXHAUST FANS (HARDWIRED INTERLOCK)
- IN MOST CASES, THE PAY BACK FOR THESE TYPES OF MEASURES WILL BE LOW, LESS THAN 1 TO 2 YEARS
- IS THE EXHAUST FAN SERVING A USEFUL PURPOSE ANYMORE (FUMES BEING GENERATED STILL, ABANDONED SMOKING LOUNGES, ETC.) OR SIMPLY A LEGACY TO A BYGONE ERA?

13 IMPLEMENTATION PHASE – BUILDING HVAC SYSTEMS AND CONTROLS

HVAC Exhaust Fan Controls – implementation suggestions:

Exhaust Fans

- Are they running, and moving air out of the building?
    1. Some might have a belt that connects the fan to the motor. Inspect the belt.
    2. Others might be a direct drive.
    3. It is a good idea to look and make sure that the fan is turning and not just making noise like it is turning and moving air.
- Are they in good condition, no missing panels or grills?
    1. A lot of exhaust fans will have an access panel that gets you into the motor and any other components inside of the exhaust fan.
- What is controlling the exhaust fan, does it turn off and on, on a schedule or some occupied sensor, or is it interlocked with the supply fan serving the same area (or the supply fan's thermostat)?
    1. Find out what is controlling the exhaust fan, note it for the report also make sure that device that is controlling the exhaust fan works.
    2. If there is nothing controlling the exhaust fan that is an opportunity in the re-tuning of the building.

Re-tuning ideas

1. Exhaust Fan not moving air
2. Exhaust Fan running 24/7
3. Exhaust Fan a legacy piece of equipment (Smoking Lounge, Photo copying machine room, etc.)? Many older buildings had dedicated exhaust fans for smoking or fume generating equipment, that are either outlawed or no longer in use today (newer photo copying machines produce no fumes or smells).

BUILDING HVAC SYSTEMS IMPLEMENTATION SUMMARY

- HEATING AND COOLING SYSTEM
  - INSPECT AND FIX OR REPLACE LOOSE FAN BELTS
  - INSPECT AND ADJUST SHEAVES FOR PROPER FAN OPERATION
  - INSPECT AND CLEAN DIRTY FAN WHEELS AND DIRTY COILS
  - INSPECT AND CLEAN CONDENSATE DRAIN PAN AND ENSURE TRAP IS PRIMED
  - INSPECT AND SECURE EQUIPMENT CABINET DOORS AND PANELS THAT ARE LOOSE
- ECONOMIZER
  - INSPECT AND REPAIR OR REPLACE BROKEN DAMPERS OR MISSING SEALS OR MISSING BLADES
  - INSPECT AND REPAIR OR REPLACE BROKEN OR IMPROPERLY ADJUSTED DAMPER LINKAGES
  - VERIFY THAT OUTSIDE AIR DAMPERS ARE CORRECTLY SET AT THEIR MINIMUM POSITION.
- PROGRAMMABLE THERMOSTATS
  - CONFIGURE PROPERLY FOR SET POINTS AND SCHEDULES THAT MATCH OCCUPANCY SCHEDULES OF BUILDING OR ZONE
  - OPTIMAL START IN PLACE AND NOT IN "HOLD" MODE
- GAS-FIRED EQUIPMENT
  - VERIFY THAT THE COMBUSTION-AIR INTAKE IS PROPERLY CONFIGURED W/NO BLOCKAGE
  - VERIFY THAT THE GAS PRESSURE REGULATOR IS SET CORRECTLY (TRAINED TECHNICIAN)

HVAC Systems Summary – implementation suggestions:

A quick check of the economizer function can be performed by taking (3) air temperature measurements as follows:

- Common Space Temperature (CSP) or Return-Air Temperature (RAT)
- Outdoor-Air Temperature (OAT)
- Mixed-Air temperature (MAT) – this will be the most difficult temperature to take

- Use the following equation to calculate the amount of outside air (as a percentage/fraction): [(CSP – MAT) / (CSP-OAT)] x 100. As an example, if the economizer is turned off (outside air dampers are at their minimum position), and the temperatures are as follows:

CSP or RAT = 72°F, OAT = 45°F and MAT = 55°F
[(72 – 55) / (72-45)] x 100 = (17/27) x 100 = 0.6296 x 100 = 62.96% Outside Air.

- If the expected percentage of outside air was 25 percent, this would show an obvious excess amount of outside air that will create additional heating load in the winter and cooling load in the summer. The cause for the excess outside air should be corrected.

- Possible causes for excess outside air when not economizing can include failed actuators, failed damper blades and linkages, failed controls or set points, failed relief dampers and other blockages in ductwork, etc. If the rooftop units have powered return/exhaust fans, they may not be working properly.

- This same formula and exercise can be used to check the economizer function during moderate weather (40-60^{o}F outside temperature conditions) when economizers should be operating instead of mechanical cooling.
- Gas pressure regulator should be verified by a trained technician as their setting can impact equipment performance.
- Condensate traps should be allowed to “go dry” when located outside in potential freezing weather climate zones, otherwise the water may freeze and crack the trap or drain line.

BUILDING HVAC SYSTEMS IMPLEMENTATION: EXERCISE

1. What are two things that we need to be aware of when verifying the location of existing thermostats (or when preparing to install new thermostats)?
2. Which thermostat has a better chance of saving energy, a programmable thermostat or a mechanical thermostat?
3. If an economizer is not operating correctly, will it affect the energy consumption of a building? If true, what about the comfort?
4. List 3 reasons economizers fail or don't work properly.
5. What are the top 2 reasons that rooftop HVAC equipment is energy inefficient?
6. View this link to see a demonstration of setting up a programmable thermostat's functions: http://www.energystar.gov/index.cfm?fuseaction=vid_gallery.showGenYTVideo

HVAC Systems Exercise:

1. Not near a heat source and not impacted by the sun (or diffuser)
2. A digital thermostat, as long as it is properly configured.
3. Yes, but the comfort may be fine as the HVAC system works harder (masks the problem) to maintain comfort set points
4. List 3 reasons economizers fail or don't work properly. **Answers: installed wrong, broken or frozen, controller and/or sensor failure.**
5. What are the top 2 reasons that rooftop HVAC equipment is energy inefficient? **Answers: economizers have failed or not working properly and improper refrigerant charge (or dirty coils and filters).**

Chapter 14: Implementation Phase – Indoor Condition

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN WHAT PRESCRIPTIVE IMPROVEMENTS TO IMPLEMENT FOR THE INDOOR CONDITION OF THE BUILDING

MATERIALS: POWERPOINT SLIDES 14 BUILDING INDOOR CONDITION IMPLEMENTATION PHASE

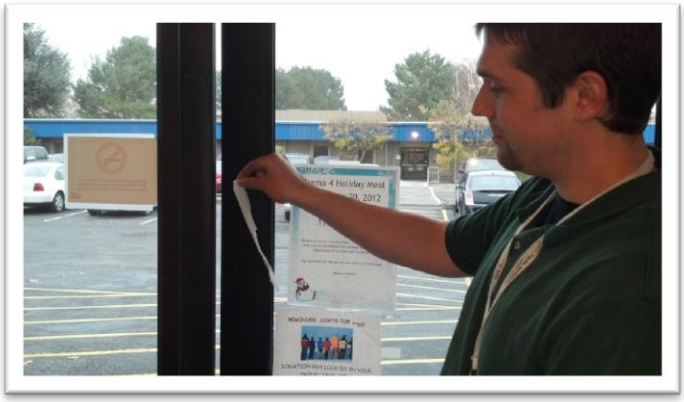
LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN IMPROVING INDOOR CONDITIONS
- WHAT TO FOCUS ON THAT MIGHT BE IMPACTING INDOOR CONDITIONS

14 RE-TUNING STEPS

BUILDING INDOOR CONDITIONS IMPLEMENTATION: BUILDING PRESSURIZATION – WHAT'S WRONG?

- A SMALL STRIP OF TISSUE PAPER IS BEING PULLED INWARD NEAR A GAP IN THE DOOR (OR SLIGHT OPENING – WHAT'S WRONG? WHAT SOLUTION DO YOU RECOMMEND?



- BUILDINGS SHOULD BE PRESSURIZED TO BE SLIGHTLY POSITIVE TO ELIMINATE UNCONDITIONED AIR FROM INFILTRATING INTO THE BUILDING. THIS BUILDING SEEMS TO BE NEGATIVELY PRESSURIZED.
- IF NEGATIVE, WHAT HVAC SYSTEMS SHOULD BE CHECKED FOR PROBLEMS?
- SIDE NOTE: DOOR GAPS INDICATE A LACK OF PROPER DOOR SEALS AND SHOULD BE FIXED.

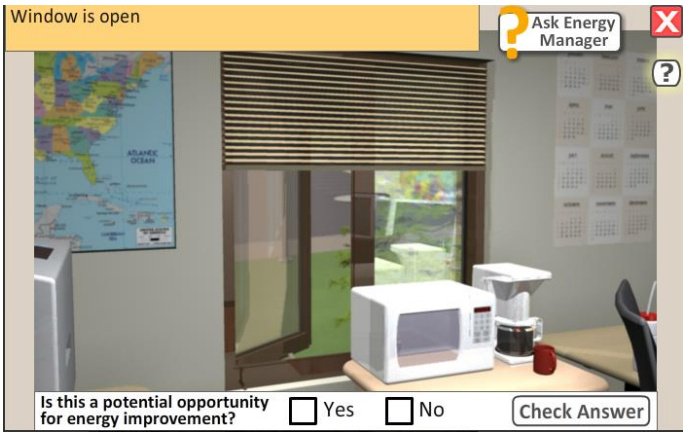
14 IMPLEMENTATION PHASE – BUILDING INDOOR CONDITION

Indoor Conditions – Building Pressurization implementation suggestions:

- Use a small piece of paper, tissue or similar material to determine if air is being pushed out of the building (building is positively pressurized), or being pulled into the building (building is negatively pressurized) at the entrance doors.
- Doing this test on a windy day may be problematic. Suggest a calm day for this test.
- Thermostats can be found on perimeter walls or support columns near perimeter windows. These locations often are impacted by outside temperature conditions if the building is negatively pressurized.
- Perimeter offices will be challenged during negative building pressurization conditions, if holes or gaps exist in the envelope (outlets, windows, etc.)
- If the building is negative earlier guidance suggested checking the intake filters and screens (if plugged, little outside air can come into the unit) and to also check the unit power exhaust fans for correct operations.

BUILDING INDOOR CONDITIONS IMPLEMENTATION: WINDOW MANAGEMENT – WHAT'S WRONG?

- THE WINDOW IS OPEN! WHAT SHOULD YOU DO?



- SOLUTION: MEASURE THE ROOM TEMPERATURE; IF IT IS TOO HOT OR TOO COLD, FIND OUT WHY – IT COULD BE AIR BALANCE PROBLEM OR EXCESSIVE HEAT LOAD
- IS THIS A SECURITY CONCERN FOR THE BUILDING?

14 IMPLEMENTATION PHASE – BUILDING INDOOR CONDITION

Indoor Conditions – Window Management implementation suggestions:

- For a lot of small commercial buildings, depending upon their business and their location, this may also be a safety or security concern.
- Periodically checking operable windows may need to be more than just an occasional exercise if safety or security is an issue.
- Discussing these issues with the building occupants is also a very good idea.
- Operable windows don't open by themselves and may be an indicator of other problems (too hot, indoor air quality issues, etc.).

BUILDING INDOOR CONDITIONS IMPLEMENTATION: OFFICE HVAC MANAGEMENT – WHAT'S WRONG?

- A PORTABLE HEATER IS RUNNING AND THE DIFFUSER IS PARTIALLY COVERED! WHAT SHOULD YOU DO?

- HEATERS UNDER DESKS AND COVERED DIFFUSERS INDICATE OCCUPANT COMFORT PROBLEMS
- SOLUTION: MEASURE THE ROOM TEMPERATURE; IF IT IS TOO HOT OR TOO COLD, FIND OUT WHY – IT COULD BE AN AIR BALANCE PROBLEM OR EXCESSIVE HEAT LOAD
- SOLUTION: ARE THERMOSTATS NOT CONFIGURED PROPERLY, AS DISCUSSED EARLIER?

14 IMPLEMENTATION PHASE – BUILDING INDOOR CONDITION

Indoor Conditions – Office HVAC Management implementation suggestions:

Internal Conditions *(Tenants, grills, office layout)*

- Are there grills that are taped off? If yes, this could indicate a problem with distribution of air or temperature control problem. There are so many things that could be the problem when you see this (Examples include thermostat location, too much air into the space, etc.).
- Are rooms and hallways comfortable, or cold and hot?
- Does the building seem stuffy or have any unusual odors? Are there indications of an exhaust air problem, or not enough fresh air being introduced into the building?
- Are there a lot of tenant complaints? Are the complaints about the temperature being too hot or too cold? Is there adequate resolution of tenant complaints?
- Are there space heaters in the offices? If yes, this could indicate a problem with temperature control or an air distribution problem.
- Has the use of the space changed? Have the office or cubicle changed in configuration (walls moved, removed, spaces combined, etc)? If yes, has the HVAC changed to meet the need of the new configuration (thermostat locations, duct and diffuser locations)?
- Talk to the tenants. Are there temperature complaints? Are the complaints at certain times of the day?
- Is there an after-hours operation for janitorial cleaning crews? If yes, when does the building get cleaned? If it is cleaned at night do the HVAC systems run to support the after-hour cleaning

efforts or are do they remain off? Do the HVAC systems need to run while janitorial crew is cleaning the building (if this is at night)?

- How are the lights controlled for the janitorial cleaning crew? How are the lights turned off after the cleaning period ends?
- How is equipment (HVAC & lights) operated for building after-hours?

Chapter 15: Implementation Phase – Lighting Systems and Controls

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN WHAT PRESCRIPTIVE IMPROVEMENTS TO IMPLEMENT ON THE LIGHTING SYSTEMS OF THE BUILDING

MATERIALS: POWERPOINT SLIDES 15 BUILDING LIGHTING SYSTEMS IMPLEMENTATION PHASE

LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN IMPROVING LIGHTING
- WHAT TO FOCUS ON WHEN IMPROVING LIGHTING CONTROLS

15 RE-TUNING STEPS

Lighting Systems and Controls Implementation: What's Wrong with this Interior Space?

- You walk into a conference room and find that it is not in use and has not been occupied in a very long time! What should you do?

- What Actions Might you Consider?
- Operable light switch signage?
- See if Existing Occupancy sensor(s) are working?
- Low-cost improvement opportunity for occupancy sensors?
- De-Lamp if the space is over-lit (measure light levels)?
- Dimmable lighting measure?

15 Implementation Phase – Building Lighting Systems and Controls

Lighting Systems and Control implementation suggestions:

- These types of space (temporary occupancy – conference rooms, bathrooms, lobbies, etc.) are ideal candidates for automatic lighting controls (occupancy or vacancy sensor technology).
- Spaces with natural day lighting may also benefit from day lighting controls.
- Some of these solutions come with cost and should be carefully applied to ensure they are sustainable.

Lighting Systems and Controls Implementation: What's Wrong with this Outside Lighting?

- You drive by your building at noon and find all the outside lights are burning bright! What should you do to remedy this situation?
- If the time clock controls are not configured, what should you do to remedy this situation?
- Inspect and adjust the timer trippers or digital settings
- If the photo cell is not working correctly, what would you do to remedy the issue? Inspect the photo cell eye and clean if dirty and/or move to better location if necessary



15 Implementation Phase – Building Lighting Systems and Controls

Lighting Systems and Control implementation suggestions:

- Proper light levels should be maintained. Use a light level meter, to ensure that the light fixtures are not over lighting the building, or under lighting if removed.
- Replace T-12 lamps with T-8s or T-5s. As T-12s are banned, this should be on a buildings' priority list. Group re-lamping may be the most efficient and economical way to undertake this effort. Consider LEDs for applications where total cost is considered. LEDs can last significantly longer than any other lighting technology and in hard-to-reach areas or high labor cost areas, these factors should be considered.
- Clean fixtures. If fixture is dirty, there is a reduction in the effectiveness of the fixture.
- Reduce exterior Lighting Power Density (LPD) and parking area lighting. Do you need all of the lights on the outside of a building on? There is usually an opportunity to reduce this lighting or turn it off because this lighting may only be needed for a small part of the night. In many cases, the lights are used for employee safety and possibly building security.
- Use CFL in place of incandescent bulbs where it makes sense. They do not have the same lighting levels that the incandescent bulbs have.
- Occupancy sensors in conference rooms, bathrooms and offices. Bathroom sensors need to control the bathroom exhaust fans. Check to see if they are working properly and turn off equipment as intended. For spaces that have low usage, this might be something that would make sense for these areas.

- Install signs at all switches that promotes saving energy by turning off lights. This is a very effective way to promote energy awareness.
- Use photo cells to control parking lots and exterior lights. It is preferable to use an astrological clock for controlling the outside lights, if reliable and not complicated. Ensure that the photo cell sensor eye is “clean”, not obscured by landscaping or in a location that will cause a false reading (resulting in lights being on all the time, or potentially off all the time).

Re-tuning Ideas

1. De-lamping interior lights
2. Replace T-12 with T-8’s or T-5’s
3. Clean fixtures
4. Reduce Exterior Lighting
5. Occupancy Sensors
6. Signage
7. Photocells / Astrological clock

Lighting Systems and Controls Implementation: outside lights

- Verify that exterior lighting for building entry points, loading docks and other exterior locations are off during the day. Otherwise determine the cause and fix.
- If the photo cell is not working correctly, what would you do to remedy the issue? Inspect the photo cell eye and clean if dirty and/or move to better location if necessary



15 Implementation Phase – Building Lighting Systems and Controls

Lighting Systems and Control implementation suggestions:

- Either a photo cell or time clock or light switch is at fault for this energy waste. In some cases, it could be as simple as a manual switch that has been left on (a manual light switch is not an automatic control solution).
- Often, photo cell controls can cause exterior lights to remain on, when cloud cover is heavy at certain times of the day (early or late), which can indicate that the sensor eye is beginning to get dirty and in need of cleaning.
- Exterior lighting control is often from a photo cell, similar to the one shown. They often become dirty over time. When natural day light cannot reach the sensor, the photo cell assumes it is dark outside (by design). This is a periodic maintenance item that requires cleaning to ensure proper operation.

Lighting Systems and Controls Implementation summary

Did you find any opportunities to:

- De-lamping interior lights
- Replace T-12 lamps with T-8s or T-5s
- Replace incandescent bulbs with CFLs or light emitting diodes (LEDs)
  - LEDs are especially good for hard to access areas (reduce maintenance $)
- Clean fixtures or lamps
- Reduce exterior lighting
- Install occupancy sensors
- Install "Turn off lights when not in use" signage at manual light switches
- Use photocells for outdoor/indoor lighting controls



15 Implementation Phase – Building Lighting Systems and Controls

Lighting Systems and Control implementation suggestions:

- Proper light levels should be maintained. Use a light level meter, to ensure that the light fixtures are not over lighting the building, or under lighting if removed.
- Replace T-12 lamps with T-8s or T-5s. As T-12s are banned, this should be on a buildings' priority list. Group re-lamping may be the most efficient and economical way to undertake this effort. Consider LEDs for applications where total cost is considered. LEDs can last significantly longer than any other lighting technology and in hard-to-reach areas or high labor cost areas, these factors should be considered.
- Clean fixtures. If fixture is dirty, there is a reduction in the effectiveness of the fixture.
- Reduce exterior Lighting Power Density (LPD) and parking area lighting. Do you need all of the lights on the outside of a building on? There is usually an opportunity to reduce this lighting or turn it off because this lighting may only be needed for a small part of the night. In many cases, the lights are used for employee safety and possibly building security.
- Use CFL in place of incandescent bulbs where it makes sense. They do not have the same lighting levels that the incandescent bulbs have.

- Occupancy sensors in conference rooms, bathrooms and offices. Bathroom sensors need to control the bathroom exhaust fans. Check to see if they are working properly and turn off equipment as intended. For spaces that have low usage, this might be something that would make sense for these areas.
- Install signs at all switches that promote~~s~~ saving energy by turning off lights. This is a very effective way to promote energy awareness.
- Use photo cells to control parking lots and exterior lights. It is preferable to use an astrological clock for controlling the outside lights, if reliable and not complicated. Ensure that the photo cell sensor eye is "clean", not obscured by landscaping or in a location that will cause a false reading (resulting in lights being on all the time, or potentially off all the time).

Re-tuning Ideas

1. De-lamping interior lights
2. Replace T-12 with T-8's or T-5's
3. Clean fixtures
4. Reduce Exterior Lighting
5. Occupancy Sensors
6. Signage
7. Photocells / Astrological clock

LIGHTING SYSTEMS AND CONTROLS IMPLEMENTATION: EXERCISE

1. True or False – Posting signs to promote turning lights off help lower energy usage?
2. Which lamps use the most power to provide the same light levels? – T-12, T-8 or T-5
3. True or False – When replacing T-12 lamps with T-8 lamps, the existing ballast can be left in place?
4. True or False – Dirty fixtures reduce the effectiveness of the light fixture?

Lighting Systems and Controls Exercise:

Answers:

1. True
2. T-12
3. False
4. True

Chapter 16: Implementation Phase – Hot Water Systems and Controls

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN WHAT PRESCRIPTIVE IMPROVEMENTS TO IMPLEMENT ON THE HOT WATER SYSTEMS OF THE BUILDING.

MATERIALS: POWERPOINT SLIDES 15 BUILDING HOT WATER SYSTEMS IMPLEMENTATION PHASE

LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN IMPROVING HOT WATER SYSTEMS
- WHAT TO FOCUS ON WHEN IMPROVING HOT WATER SYSTEM CONTROLS

16 RE-TUNING STEPS

Building Hot Water Systems Implementation: Hot Water Systems and Controls

Did you find any opportunities to:

- Use controls to turn off domestic hot water tanks at night or when not needed
- Lower the domestic hot water temperature set point (most municipality codes do not allow set points above 125F for scalding issues)
- Use controls to turn off heating hot water boiler(s) at night or when not needed
- Lower the heating hot water temperature set point
- Use controls to turn off turn off hot water circulating pumps at night or when not needed
- Insulate tanks and piping
- Fix leaks
- Use controls to disable heating hot water systems when outside air temperatures are greater than 50 to 60°F

16 Implementation Phase – Building Hot Water Systems and Controls

Hot Water Systems and Controls implementation suggestions:

Most municipality codes do not allow public buildings to have domestic hot water temperatures in excess of 120°F (scalding issue).

Prescriptive improvements:

1. Lower the set points if possible.
2. For gas-fired systems, ensure the gas pressure regulator is set correctly.
3. Install hot water tanks that are “Energy-Star” rated.
4. If the pump is VFD-driven consider lower speed at night or during low load periods.
5. Set back controls in place?
6. Time clocks working correctly?
7. Turn off at night, or reduce at night.
8. Tanks and piping properly insulated? If not, install insulation where missing.
9. Fix dripping faucets and leaking pipes.

LIGHTING SYSTEMS AND CONTROLS IMPLEMENTATION: EXERCISE

1. What is the maximum temperature setting for domestic hot water to mitigate scalding?
2. True or False – Leaks that are found on hot water systems can be ignored?
3. What will happen if hot water lines are not properly insulated?
4. Circulating pumps for domestic hot water systems should be shut off during vacancy periods. Do you know when the building is not occupied?
5. Heating hot water systems can be turned off above what outside air temperature?

16 IMPLEMENTATION PHASE – BUILDING HOT WATER SYSTEMS AND CONTROLS

Hot Water Systems and Controls Exercise:

Answers:

1. Most municipality codes will not allow domestic hot water temperatures > 120-130^{o}F
2. False
3. Heat loss will occur, adding additional load to the hot water system (this heat may be adding to your building HVAC cooling loads).
4. Generally at night and weekends, but that is building specific and should be determined by the owner or facility manager.
5. 50-60^{o}F

Chapter 17: Implementation Phase – Air Distribution Systems

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: LEARN WHAT PRESCRIPTIVE IMPROVEMENTS TO IMPLEMENT ON THE AIR DISTRIBUTION SYSTEMS OF THE BUILDING.

MATERIALS: POWERPOINT SLIDES 15 BUILDING HOT WATER SYSTEMS IMPLEMENTATION PHASE

LEARNING OBJECTIVES:

- WHAT TO FOCUS ON WHEN IMPROVING AIR DISTRIBUTION SYSTEMS

17 RE-TUNING STEPS

Building Air Distribution Systems Implementation: Re-Sealing Ductwork

If a duct leak is found, how do know how to repair it?

- The best options for re-sealing sheet metal ductwork is to re-attach the ductwork with screws and re-seal with a UL listed tape or duct sealer
- Ductwork may need additional support to prevent the ductwork from coming apart again

17 Implementation Phase – Air Distribution Systems

Building Air Distribution Systems Implementation: Re-Sealing Ductwork

If a duct leak is found, how do know how to repair it?

- For flexible ductwork, there are a couple of options for repair:
  - 1st, remove the damaged ductwork and attach the new piece of ductwork
  - 2nd, splice in a piece of round sheet metal ductwork for the damaged flexible ductwork (need to insulate the piece of round sheet metal ductwork)
  - In both cases, a UL listed ductwork sealing tape should be used
- Fiber board ductwork, also has a couple of repair options:
  - 1st option, replace with sheet metal. (Maybe the most difficult option)
  - 2nd option, replace with fiber board, if the tools are available. (The easiest repair option)
  - Both options will need sealing with an UL listed sealer, and extra reinforcement is generally needed when repairing this type of ductwork

17 Implementation Phase – Air Distribution Systems

Air Distribution Systems – implementation suggestions:

1. Access attics and crawl spaces to verify ducts as necessary – be careful when in these spaces (animals, insects, heat, obstructions, etc.). Look for ductwork that is crushed or flattened, ductwork that is sagging or no longer attached to its support hangers, dirty/dust trails near joints or seams in the ductwork, tape or insulation that is not attached or hanging from the ductwork.
2. Excessive duct vibration should be explored for root cause of initial duct failure (poorly installed, somebody stepped on it when it was not designed for the load, etc) or possibly noise transmission from the fan and motor, indicating a problem with the fan/motor assembly – possibly about to fail.
3. If recent remodel or other work was done in this area (above the drop or hard ceiling), it is prudent to spot check the integrity of various system components after contractors or maintenance staff have been working above ceiling spaces where ductwork and other building systems are located.
4. The use of a thermal imaging camera (if available) will also help spot air leaks, both in summer (cooling) and winter (heating). Significant temperature contrasts in a thermal image will quickly pinpoint the source of leaks. If a thermal imaging camera is not

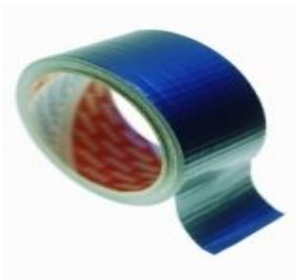
available, than finding the source of leaks will require more persistence and effort. Professionals rely more and more upon the use of thermal imaging cameras to find these types of problems.

5. Have a professional perform a duct leakage test. Air leakage rates may increase over time because of: Construction (adding to or disturbing the ductwork), damaged ductwork (from maintenance/other activities), exposure to the outdoor elements causing damage to the duct material, operational changes in duct static pressure set points (increased static), etc.
6. Ductwork that is not sealed correctly can cause the building to become depressurized. This can allow unconditioned and unfiltered air into the building. This can lead to health problems for the occupants of the building. Improperly sealed ductwork can lead to comfort problems. Sometimes it will only show when the building is subjected to temperature extremes that are at or near the design temperature of the building design conditions.
7. The potential for duct leakage can also be validated by air balance efforts that document supply fan air flows (duct traverse readings) which should closely match the total airflows measured at all connected diffusers (measured with a hood flow apparatus).
8. Un-insulated ductwork is almost as bad as leaky ductwork. Although the air is not leaking, there is significant heat loss/gain as the conditioned air flows through un-insulated ductwork. This can be even more pronounced when the ductwork is in attic spaces or on roofs, exposed to hot or cold temperatures.

- Fan Power design requirements for new offices mandate <1.5 BHP/1000 CFM.
- Duct sealing requirements are broken into 3 classes (Class C – transverse joints only, Class B – transverse joints and longitudinal seams and Class A – transverse joints, longitudinal seams and all applicable duct penetrations). Depending upon the design class, the effort required (and cost) must be applied to duct sealing in new construction. These classifications determine where sealant must be applied and do not necessarily determine the air leakage rates. Air leakage rates are impacted by construction methods, workmanship, operational fan static pressures, duct design, reheat and VAV boxes and other miscellaneous devices installed in the ductwork.
- ASHRAE 90.1, ASHRAE 189 and IECC should be reviewed for further code information.

BUILDING AIR DISTRIBUTION SYSTEMS IMPLEMENTATION: RE-SEALING DUCTWORK

- TAPE (UL 181 LISTED/RATED TAPE) – MOST OF THESE TAPES HAVE A VERY ADEQUATE STICKING BACKING THAT WILL ALLOW THE TAPE TO STICK IN A WIDE TEMPERATURE AND CONDITION RANGE. IT ALSO HAS A THIN METAL-FILMED BACKED TAPE DESIGN, TO PROVIDE ADDITIONAL STRENGTH.
- INDOOR/OUTDOOR RATED DUCT SEALER – THESE SEALERS ARE GENERALLY PAINTED ON WITH A PAINT BRUSH OR ARE IN A TUBE OF CAULK.
- AEROSOL DUCTWORK SEALANT NEEDS TO BE DONE BY A TRAINED PROFESSIONAL. THIS TYPE OF DUCT SEALING IS DONE BY SPRAYING AEROSOL SUBSTANCES DOWN THE DUCTWORK, WHICH WILL STICK TO THE HOLES IN THE DUCTWORK AND SEAL ANY OPENING, PREVENTING THE LOSS OF AIR.
- **NOT DUCT TAPE** – STUDIES HAVE BEEN DONE ON MANY DIFFERENT TYPES OF TAPE TYPE DUCT SEALERS. THE ONE THAT FAILED THE QUICKEST WAS DUCT TAPE!



17 IMPLEMENTATION PHASE – AIR DISTRIBUTION SYSTEMS

Air Distribution Systems – implementation suggestions:

- These types of repairs might better be performed by trained and qualified personnel. If the repairs are performed by in-house maintenance personnel, they should be advised by qualified personnel to ensure the repairs meet or exceed minimum construction standards.
- Once repairs are made, the repaired components should periodically be reviewed to ensure the repair persists (sustainable).

Chapter 18: Meter data profile analysis

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: DISCOVER WHAT METER DATA IS AND HOW IT CAN AID IN RE-TUNING OF THE BUILDING

MATERIALS: POWERPOINT SLIDES 18 METER DATA PROFILE ANALYSIS

LEARNING OBJECTIVES:

- HOW TO ANALYZE BUILDING METER DATA

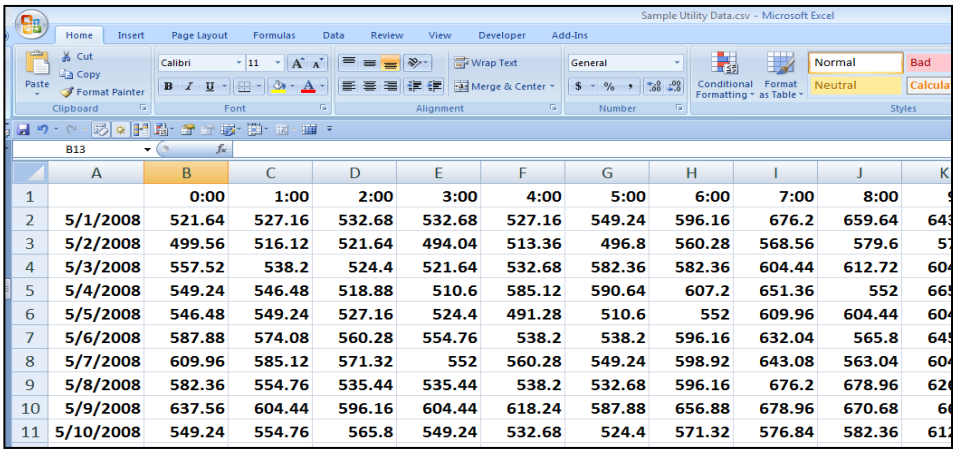
18 RE-TUNING STEPS

Building Meter data profile analysis

- Meter profiles are like a heartbeat; it should show a variation as the building consumption goes up and down as the demand for services increases
- Periodic review of the meter profile will reveal inconsistent usage
  - This requires high resolution data, 15-minute up to hourly
  - Monthly billing data will provide some useful information, but does not show time-of-use of the end-use data.
- Utilities in many regions are installing interval meters that provide high resolution (typically 15-minute) interval data
- Data from the utilities can be downloaded from the utilities' website
  - Data is typically updated daily and up to 12 months of data is typically available online
- Smart meters may also be installed on the building, and if so, should be utilized to collect the building or end-use data for analysis

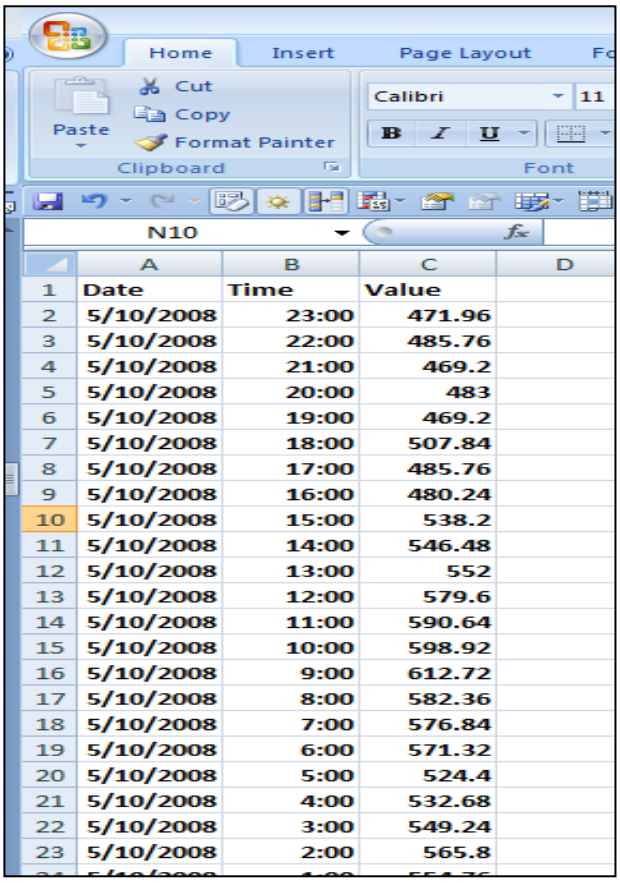
18 Meter data profile analysis

BUILDING METER DATA PROFILE ANALYSIS



	A	B	C	D	E	F	G	H	I	J	K
1		0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	
2	5/1/2008	521.64	527.16	532.68	532.68	527.16	549.24	596.16	676.2	659.64	643
3	5/2/2008	499.56	516.12	521.64	494.04	513.36	496.8	560.28	568.56	579.6	57
4	5/3/2008	557.52	538.2	524.4	521.64	532.68	582.36	582.36	604.44	612.72	604
5	5/4/2008	549.24	546.48	518.88	510.6	585.12	590.64	607.2	651.36	552	665
6	5/5/2008	546.48	549.24	527.16	524.4	491.28	510.6	552	609.96	604.44	604
7	5/6/2008	587.88	574.08	560.28	554.76	538.2	538.2	596.16	632.04	565.8	645
8	5/7/2008	609.96	585.12	571.32	552	560.28	549.24	598.92	643.08	563.04	604
9	5/8/2008	582.36	554.76	535.44	535.44	538.2	532.68	596.16	676.2	678.96	626
10	5/9/2008	637.56	604.44	596.16	604.44	618.24	587.88	656.88	678.96	670.68	66
11	5/10/2008	549.24	554.76	565.8	549.24	532.68	524.4	571.32	576.84	582.36	612

- SMART UTILITIES TYPICALLY PROVIDE DATA IN THE ABOVE FORMAT, WHICH SHOULD BE CONVERTED TO THAT BELOW:
- ENERGY CHARTING AND METRICS (ECAM) TOOL CAN CONVERT THE DATA TO THAT BELOW FOR YOU, AND IS FREELY AVAILABLE FOR MICROSOFT EXCEL USERS AT WWW.PNNL.GOV/BUILDINGRETUNING/ECAM.STM
- INCLUDED ON THE WEBSITE ARE PRACTICE DATA AND A WEBINAR SERIES FOR FIRST-TIME USERS



	A	B	C	D
1	Date	Time	Value	
2	5/10/2008	23:00	471.96	
3	5/10/2008	22:00	485.76	
4	5/10/2008	21:00	469.2	
5	5/10/2008	20:00	483	
6	5/10/2008	19:00	469.2	
7	5/10/2008	18:00	507.84	
8	5/10/2008	17:00	485.76	
9	5/10/2008	16:00	480.24	
10	5/10/2008	15:00	538.2	
11	5/10/2008	14:00	546.48	
12	5/10/2008	13:00	552	
13	5/10/2008	12:00	579.6	
14	5/10/2008	11:00	590.64	
15	5/10/2008	10:00	598.92	
16	5/10/2008	9:00	612.72	
17	5/10/2008	8:00	582.36	
18	5/10/2008	7:00	576.84	
19	5/10/2008	6:00	571.32	
20	5/10/2008	5:00	524.4	
21	5/10/2008	4:00	532.68	
22	5/10/2008	3:00	549.24	
23	5/10/2008	2:00	565.8	

18 METER DATA PROFILE ANALYSIS

Chapter 19: Documentation Phase and Calculated Savings

INSTRUCTOR GUIDANCE

TIME: 15 MINUTES

LESSON GOAL: GO OVER DOCUMENTATION OF MEASURES AND SHOW A METHOD TO CALCULATE SAVINGS FROM IMPLEMENTATION OF MEASURES

MATERIALS: POWERPOINT SLIDES 19 DOCUMENTATION PHASE AND CALCULATED SAVINGS

LEARNING OBJECTIVES:

- HOW TO DOCUMENT THE MEASURES IMPLEMENTED AND CALCULATE SAVINGS

19 RE-TUNING STEPS

Documentation Phase and Calculated Savings

- Document prescriptive re-tuning measures by cost (no/low-medium-high)
- Select which measures are appropriate for implementation for the building based on:
  - Cost
  - Ease of implementation
  - Return on Investment
  - Indoor environmental improvement
  - Safety and security
- Document the selected measures so that calculation and realization of energy savings is possible

19 Documentation phase and calculated savings

Documentation Phase and Calculated Savings

- Post Re-Tuning: calculated energy savings – overview of approach
- Calculated as the difference between the actual energy use in the post re-tuning 12 months and the energy use that would have occurred during the same 12 months if the building had not been re-tuned

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

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

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

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

19 Documentation phase and calculated savings

Air Distribution Systems – implementation suggestions:

It should be noted that $E_{base,j}$ cannot be measured directly, but rather must be estimated using a model of how the building performed prior to re-tuning. Regression models should be used based on monthly energy use during the 12 months prior to re-tuning and the corresponding outdoor-air temperatures. Then, the temperatures during the post re-tuning 12 months can be compared to the actual consumption during the post re-tuning 12 months to determine the energy savings.

Chapter 20: Conclusions

- Re-Tuning is an ongoing process
  - Do it quarterly or at least every six months OR
  - If you see an increase in energy consumption or occupant complaints
- Every set point adjustment you make will have an impact of some sort on the utility meter
- You can save energy and keep staff comfortable
- It takes time to tune a building; there are no magic set points that work all the time
- Look at the big picture when making adjustments
- Learn and know your building's personality
- Basic Energy Management
  - If you do not need it, turn it off
  - if you do not need it at full power, turn it down
  - Make the energy system smart when adjusting to the real needs of the building