Identifying Opportunities for Operational Improvement

Using Non-Invasive Methods

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Smart Buildings Center
smartbuildingscenter.org

Image source: Image by Jorge Molina from Pixabay

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NEEC's mission is to promote energy efficiency policies, programs and technologies that create jobs and foster economic growth and environmental improvement

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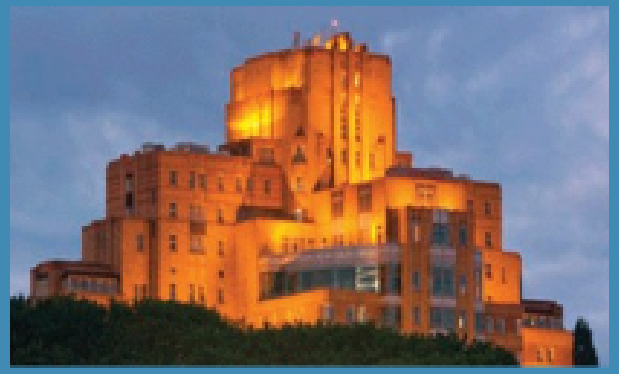

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Non-profit Education Program

Events - Networking

Training – Classes, Webinars

Demonstration – Data Visualizations,
Tool Lending Library

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TOOL LENDING LIBRARY

- Diagnostic & monitoring tools
- 85 tool types
- Online reservation system
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- Local pickup or shipped

FREE !!!

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Meeting the challenge of an evolving workforce

Smart Buildings Need Smart Operators!

- Continuing trend toward sensor-based building system automation
- Operator skill sets diversifying:
  - Mechanical
  - Technical
  - Data Analysis
  - Communication

Certified Building Operators in the PNW save their orgs up to $20,000 annually!

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Objectives

- Discuss the importance of building re-tuning
- Learn about useful monitoring and diagnostic tools
- Discuss non-invasive methods to identify opportunities for energy savings and operational improvement
- Learn how to analyze data for specific use cases

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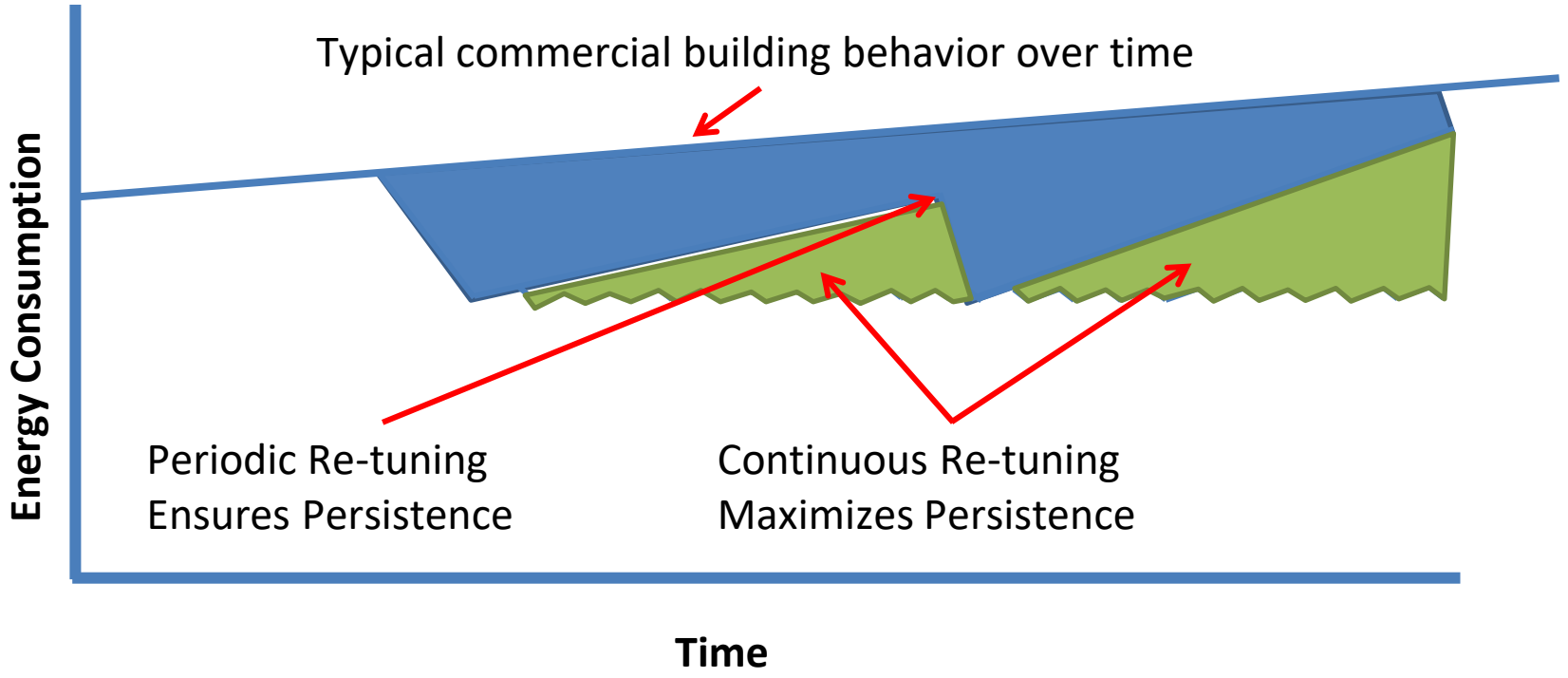
Life Cycle of Building Re-Tuning (or Re-Commissioning)



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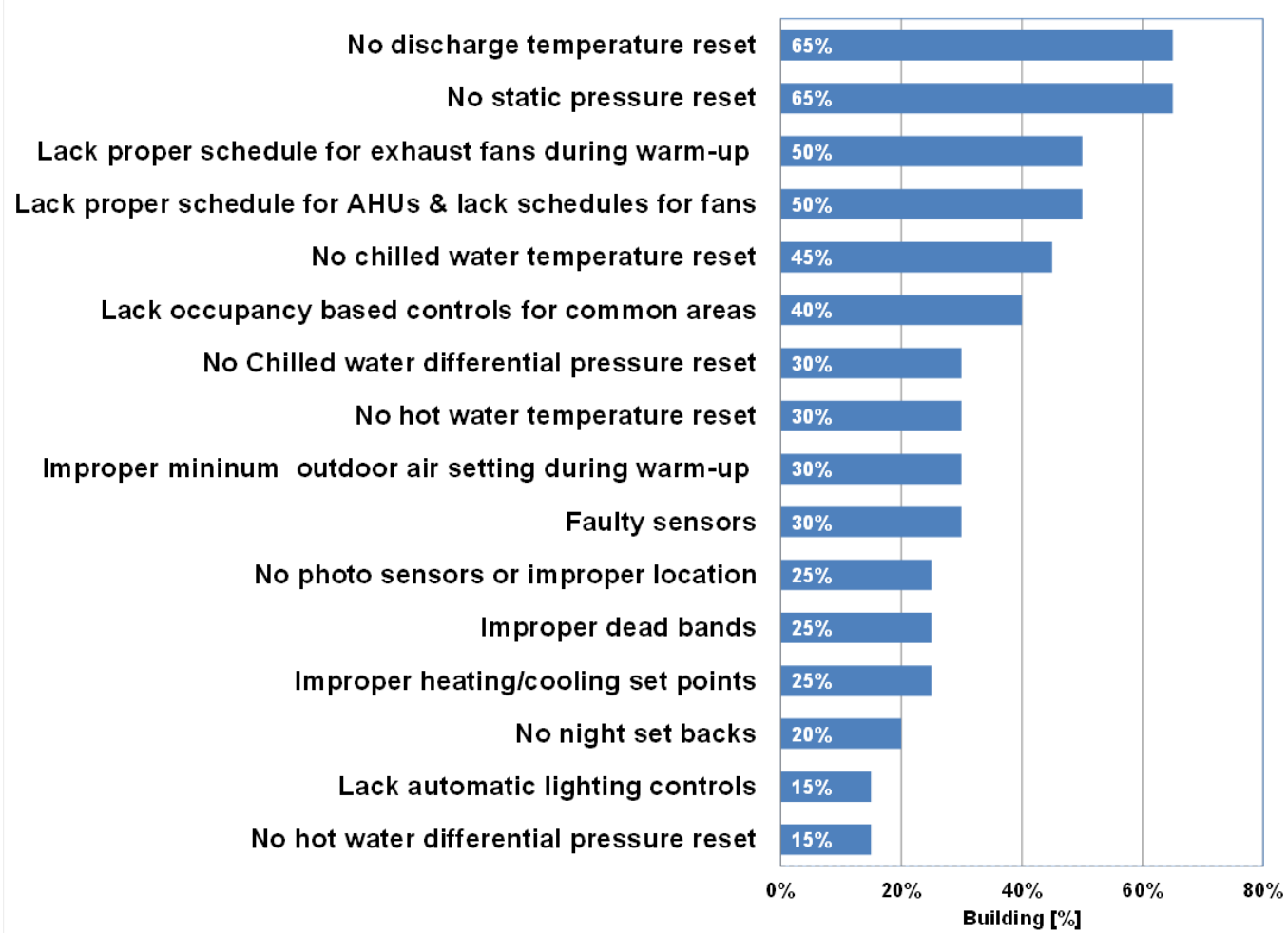
Common Re-tuning Measures: PNNL Analysis of 100 Buildings



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Building Re-tuning
Major Focus Areas

1. Heating, Ventilation and Air-Conditioning Systems and Controls
2. Lighting System and Controls
3. Domestic Hot Water
4. Water Use
5. Building Envelope

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Building 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 building needs
- Save energy without negatively impacting the comfort of the occupants

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Building Re-tuning Approach

Use a **four step approach**

1. **Initial data collection phase:** Collection of information about the building
2. **Investigation phase:** Building walk down to identify and characterize the building operations
3. **Implementation phase:** Application of prescriptive re-tuning measures
4. **Documentation phase:** Reporting of measures implemented and calculation of energy savings

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Building Walk Down: Guidance

- While walking down to investigate the building's condition and operations, be vigilant, use your senses – look, listen, smell and touch (be careful!)
- If possible, perform the walk down during both occupied hours and unoccupied hours

"You can observe a lot by just watching."
—Yogi Berra

- A lot of energy waste typically occurs during unoccupied periods and holidays
- Walk down at least once during the heating season and the cooling season
- Document your observations

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Sampling is OK

- Where there are multiple pieces of similar equipment use sampling in your investigation
  - Observe and test 12% of equipment type
  - But no fewer than a sample size of 10 for buildings <100,000 sf and no fewer than 20 for buildings >=100,000 sf

Heat Pumps

VAV Terminal Units

VRF Terminal Units

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Building Walk Down:
Tools to Carry

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Safety Check-in

Image source: Mitchellinstrument.com

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HVAC Assessment Elements

1. Equipment scheduling
2. Review setpoints
3. Review reset schedules and setpoints
4. Review optimum start/stop if applicable
5. Sensor calibration (critical sensors)
6. Controls functional testing
7. Simultaneous heating and cooling
8. Air balance issues
9. Ventilation
10. Identify any “rogue” temperature zones on multi-zone systems
11. Recommended maintenance, cleaning and repair

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Data Logging Applications

- Confirm equipment start/stop schedules
- Verify HVAC setpoints
- Measure and control plug loads
- Troubleshoot hot/cold calls
- Troubleshoot lighting control systems

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HVAC Equipment Scheduling

- Small/medium-sized commercial buildings typically lack central controls
- Typically have wall mounted thermostats to control both heating and cooling systems
- While surveying the thermostats and their capabilities, check:
  - Location of thermostat? Does sun shine on it?
  - Type of thermostat, mechanical or digital?
  - If digital, is it programmable?
  - If mechanical, replacing it with a programmable digital thermostat will save energy, if it is properly programmed

Equipment Start/Stop Schedules

Application: Supply fans, return fans, exhaust fans, boilers, chillers, circulation pumps

Diagnostic Approach: Log equipment operating schedule and compare to building occupancy

Onset Hobo Motor Logger

Dent ElitePro XC Energy logger

Fluke 1730 Energy Logger

Dent Motor Maglogger

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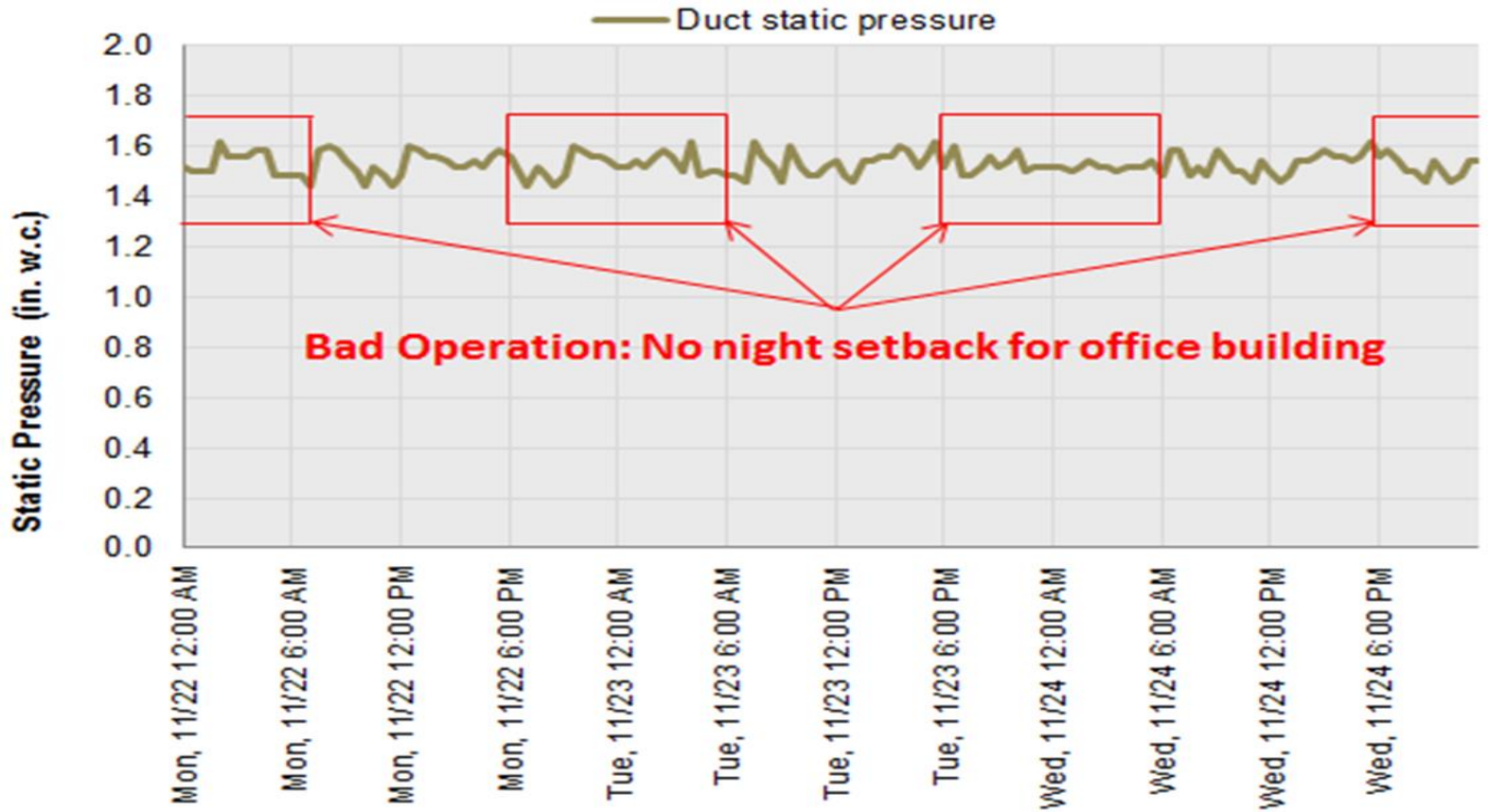
Occupancy Scheduling:
Set back for Unoccupied Hours



During unoccupied hours, the system should be set back so that the system does not continue to operate

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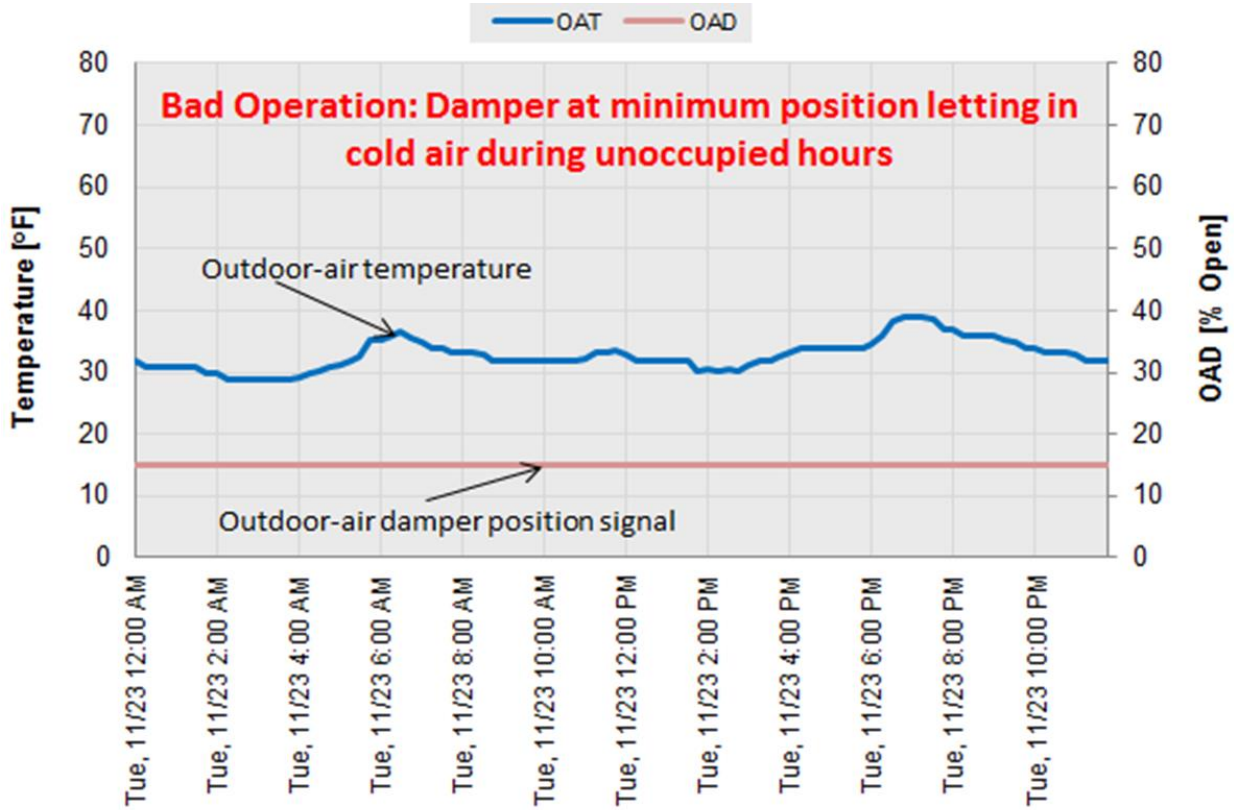
Outdoor Air Damper during Unoccupied Hours



The outdoor-air damper should close at the end of the occupied time, and stay closed overnight.

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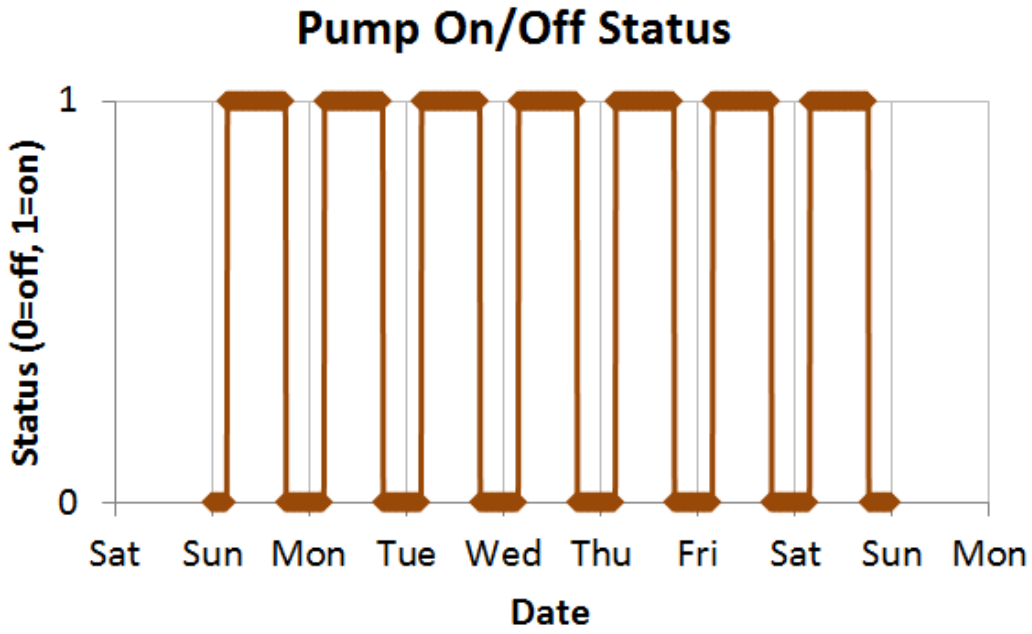
Equipment Scheduling
Motor Logger

Use BAS trend data or data logger to verify start/stop scheduling of fans and pumps



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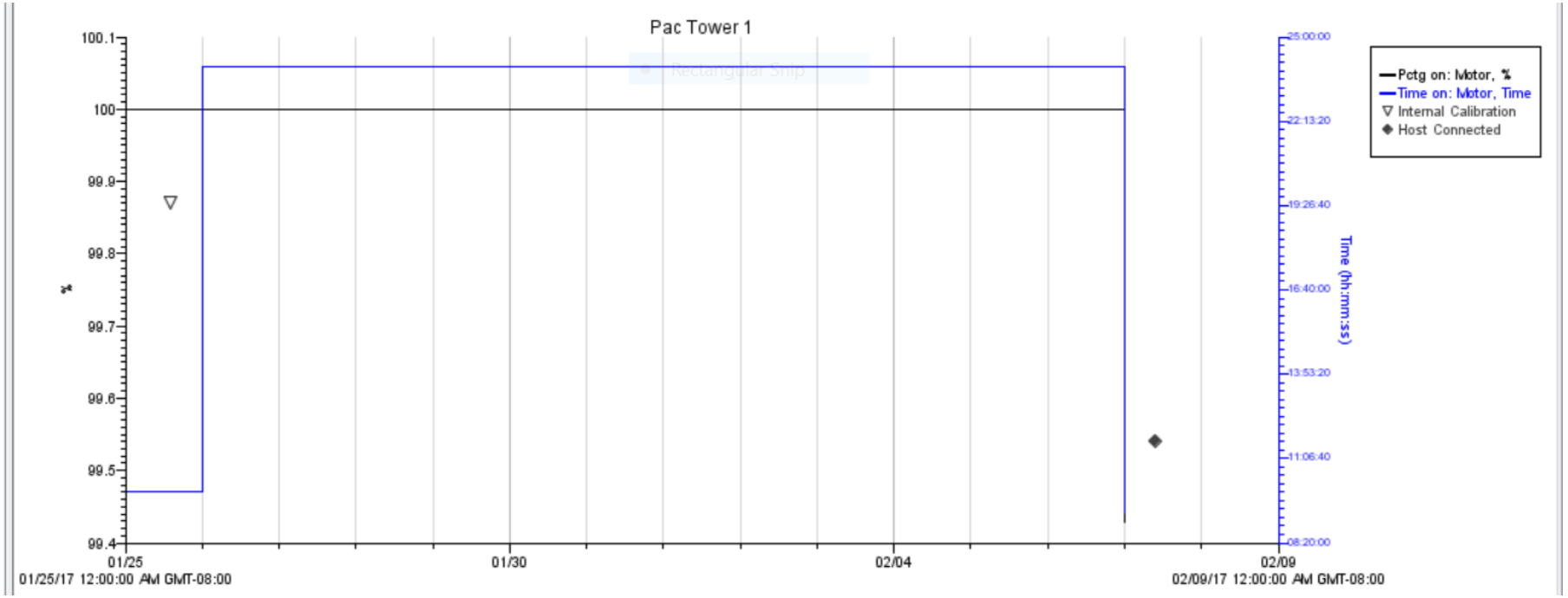
Logger Placement

Logger indicates
motor on/off status

Image courtesy of Onset Computer Corp.

Example Motor Logger Data

Fan Motor on VAV
Box running 24/7



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Verify HVAC Setpoints

Application: Zone temperature, supply air temperature, boiler supply water, outside air temperature,

Diagnostic Approach: Measure or log temperature conditions and compare to setpoint

Digital psychrometer

Laser Thermometer

Thermal Anemometer

Wifi Temp Logger

Temp/Humidity logger

4-channel data logger

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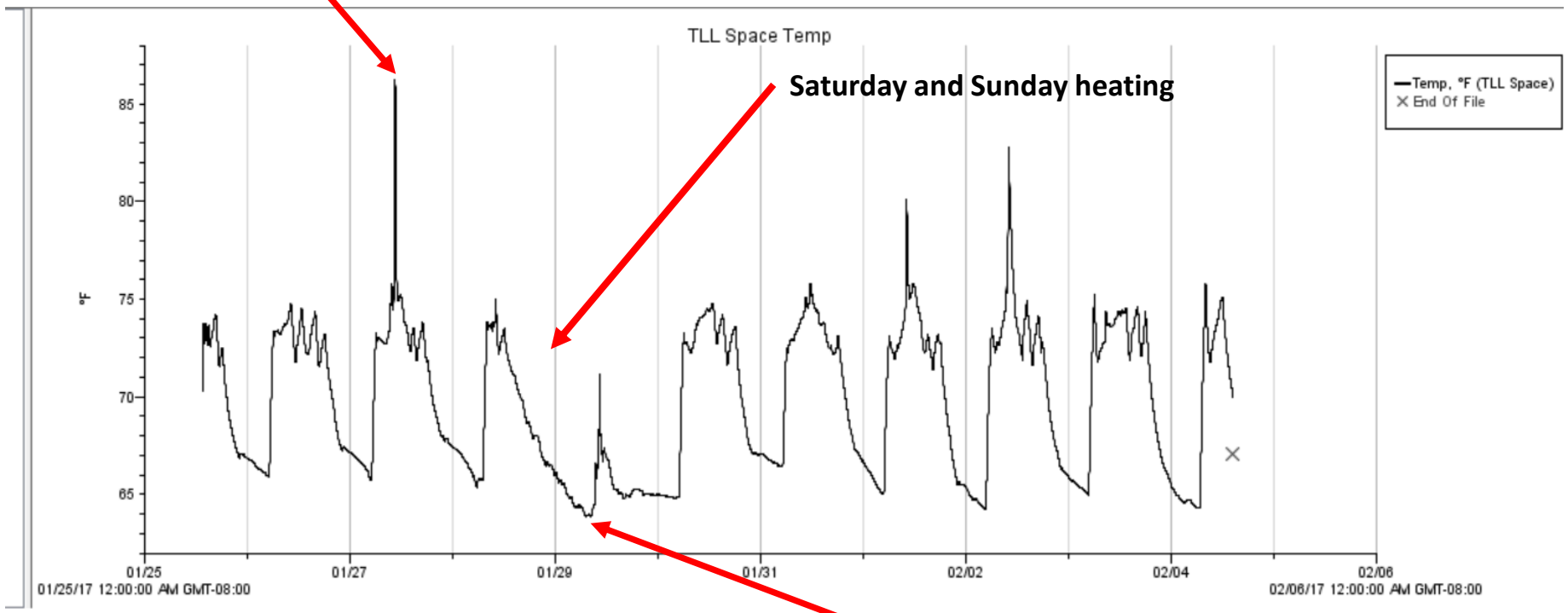
Example Room Temperature Log

Direct sunlight on t-stat triggers cooling



Saturday and Sunday heating

65F Setback temperature

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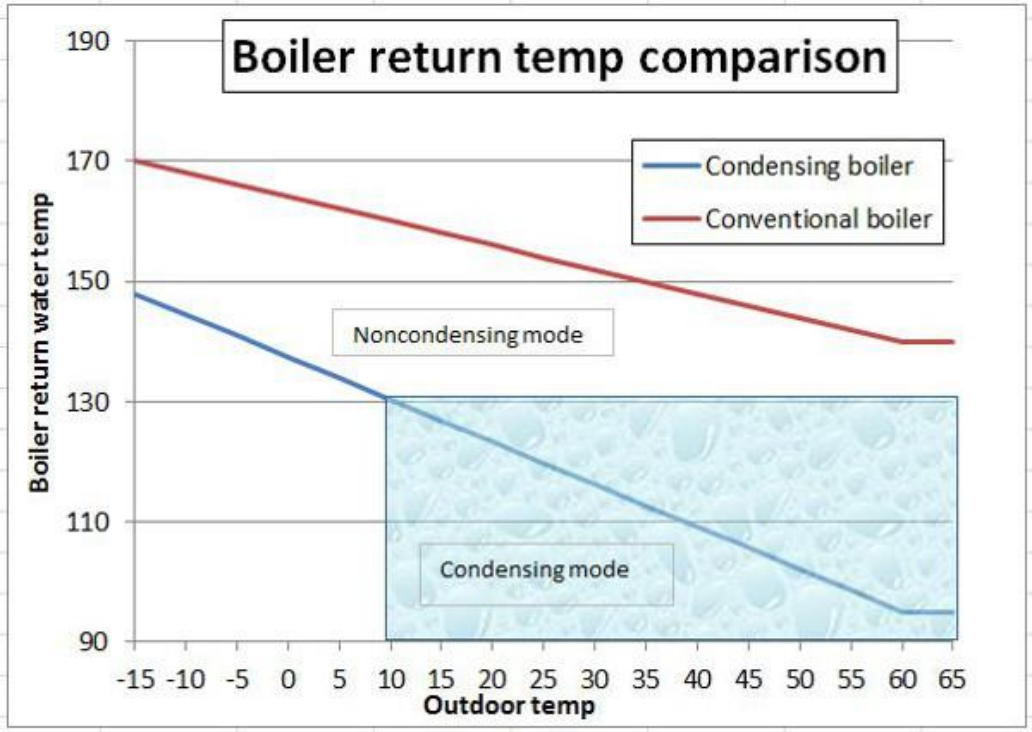
Trends to Look for: Zone Conditioning

- Is there night-time set back/unoccupied mode at the zone level?
- Is there significant reheat occurring at the zones, especially interior zones or during summer (cooling) seasonal periods?
- Excessively high minimum air flow rates for VAV terminal boxes may result in significant reheat, especially if the primary air temperature is extremely low
- Compare minimum airflow set points to maximum airflow set points (ratio). If the minimum is more than 50% of the maximum, this could indicate excessive ventilation and/or terminal box airflow rates when the space is trying to heat.
- How many zones are in heating mode and how many are in cooling mode?
- Occupant complaints (temperature or indoor air quality) may be related to the zone conditioning.
- Cold complaints may indicate AHU primary air temperatures that are too cold (does the AHU reset the discharge-air temperature set point?) and/or may indicate terminal box minimum airflow rates that are too high.

Review Reset Schedules & Setpoints

1. HW loop temperature
2. CHW loop temperature
3. HW loop differential pressure
4. CHW loop differential pressure
5. Discharge air temperature
6. Duct static pressure
7. Optimum start



Set or adjust to optimize function and energy efficiency – Use your judgement!

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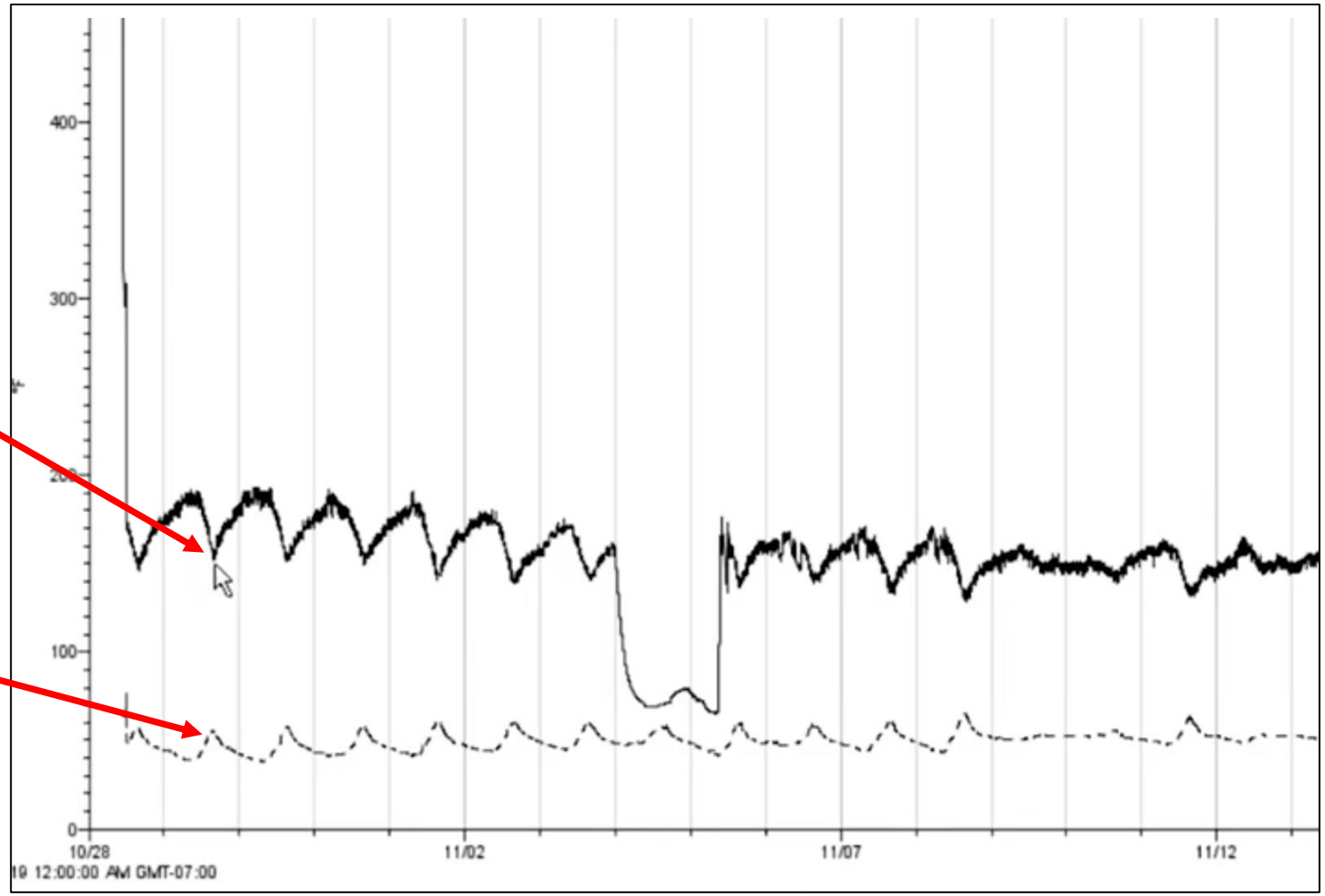
Example Supply Reset Log



Saturday and Sunday heating

Sensor Calibration

Check sensor error for critical sensors

1. Outside air temperature
2. Discharge air temperature
3. HW loop supply & return temperature
4. CHW loop supply and return temperature
5. CO2 sensors
6. Condenser water supply and return temperature

Identify where sensors should be replaced. Adjust or replace as required.

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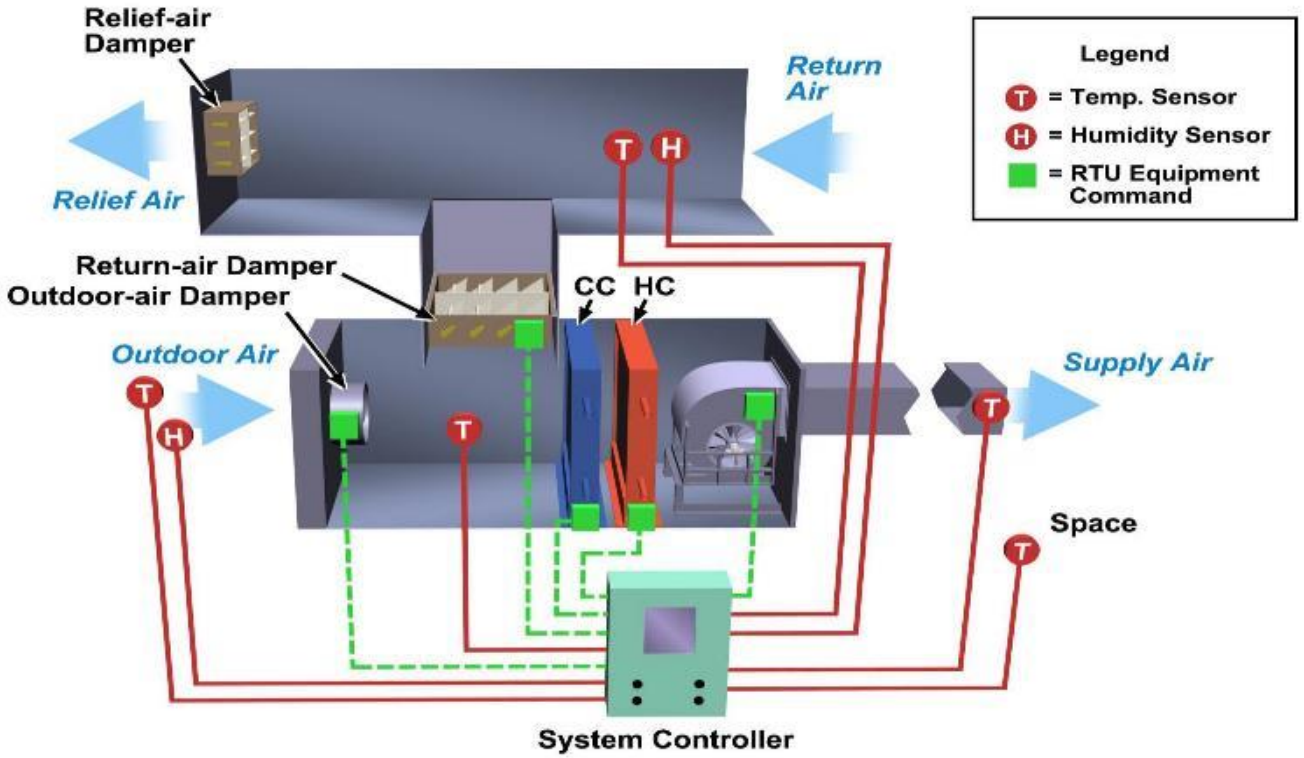
HVAC Controls Functional Testing



Functionally test all modes of operation

- Occupied
- Unoccupied
- Warm-up
- Over-ride
- Others…

Adjust control sequences as appropriate for current facility requirements

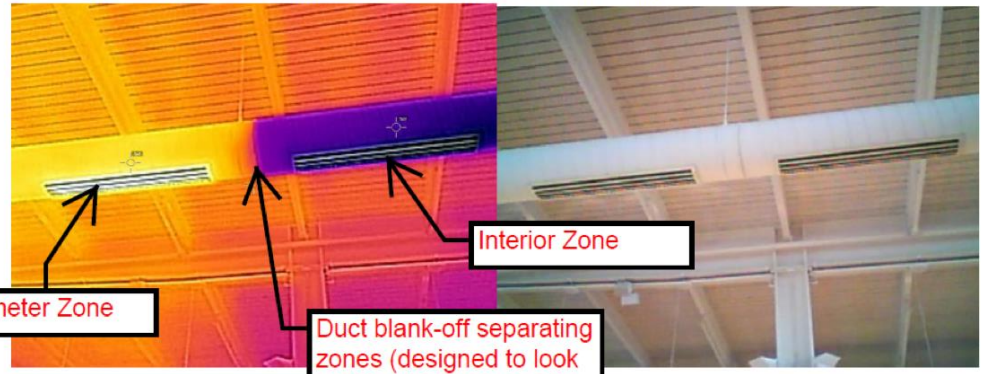
Simultaneous Heating & Cooling

Review HVAC control sequences for unintended instances of heating and cooling

- IR images of coils
- Cooling with perimeter heat
- 4-pipe fan-coils
- Large open spaces with multiple HVAC systems
- Heat/cool lockouts

Open Office on Upper Level – VAV's serving same open area operating in both heating/cooling

Open Office on Upper Level – adjacent diffusers in heating and cooling



Adjust control sequences as to reduce or eliminate and unintended simultaneous heating & cooling

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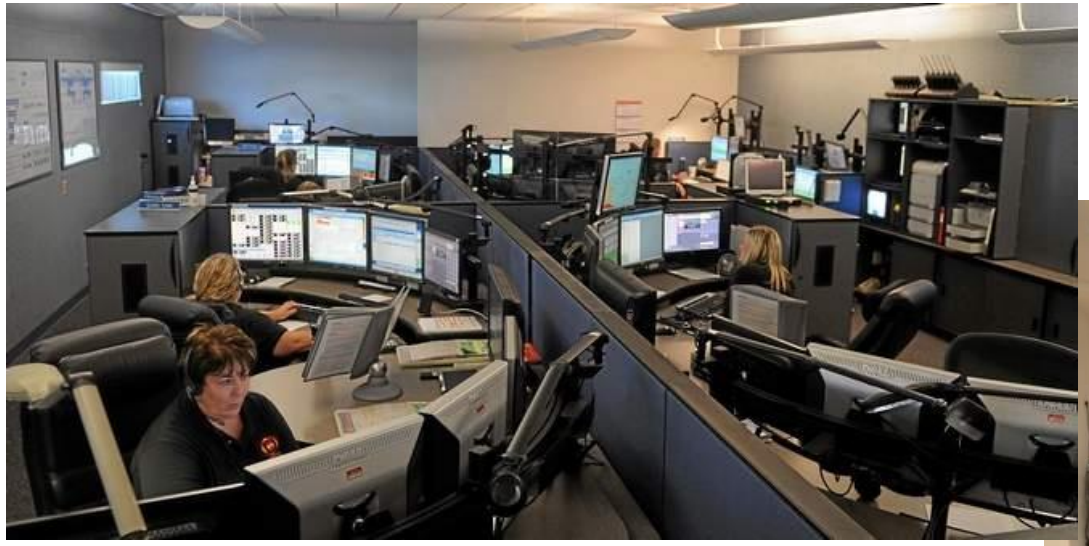
Identify Zones Dominating Multiple Zone Systems



24/7 dispatch center in an office building

Server Rooms Served by Central HVAC

Identify zones that may be dominating multi-zone system operations.
Recommend solutions to isolate these zones.

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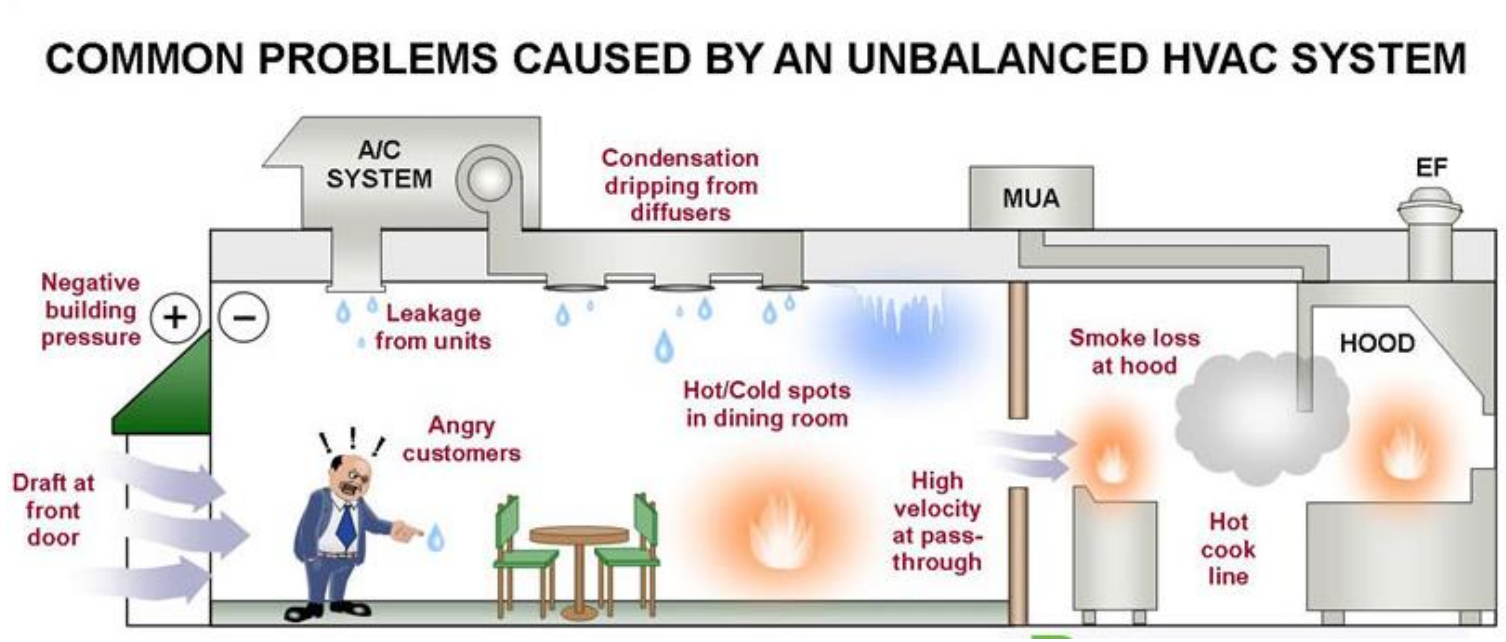
Air Balance Issues



Note any indications of significant air balancing issues. Recommend re-balancing where significant efficiency or comfort improvements can be achieved

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Compressed Air or Steam – Leak Detection

Image source: Superior AccuTrak

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HVAC Maintenance, Cleaning & Repair

What to look for:

- Dirty filters, ducting, grilles, coils
- Missing or damaged panels/access doors or seals
- Missing or damaged mechanical items (fan motors/blades/belts, pulleys)
- Missing or damaged duct and pipe insulation
- Stuck HVAC dampers
- Equipment at the end of its service life

Clean or replace filters, repair damaged equipment, repair/adjust faulty dampers.

Jammed/Frozen Damper

Disconnected Damper

Wired poorly

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Lighting System & Controls

Application: Evaluating light levels and automatic control systems

Diagnostic Approach: Measure light levels and compare to standards, verify correct operation of occupancy sensors

Light Level logger

Light/Occupancy

Lighting meter

LED Lighting meter

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Lighting Levels

- Spot check lighting levels by use type
  - Identify areas where the lighting power density could be reduced

Activity	Space Types	Recommended Illumination (lux)	Foot Candles (FC)
Public areas with dark surroundings	Parking garage	20 - 50	2-5
Simple orientation for short visits	Lobbies, storage areas, corridors	50 - 100	5-10
Working areas where visual tasks are only occasionally performed	Waiting areas, auditoriums	50 - 150	5-15
Easy Office Work, Classes	Certain offices and classrooms	200-300	20-30
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	Certain offices, classrooms, libraries	350-500	35-50
Retail	Supermarkets, Mechanical Workshops	300-800	30-80

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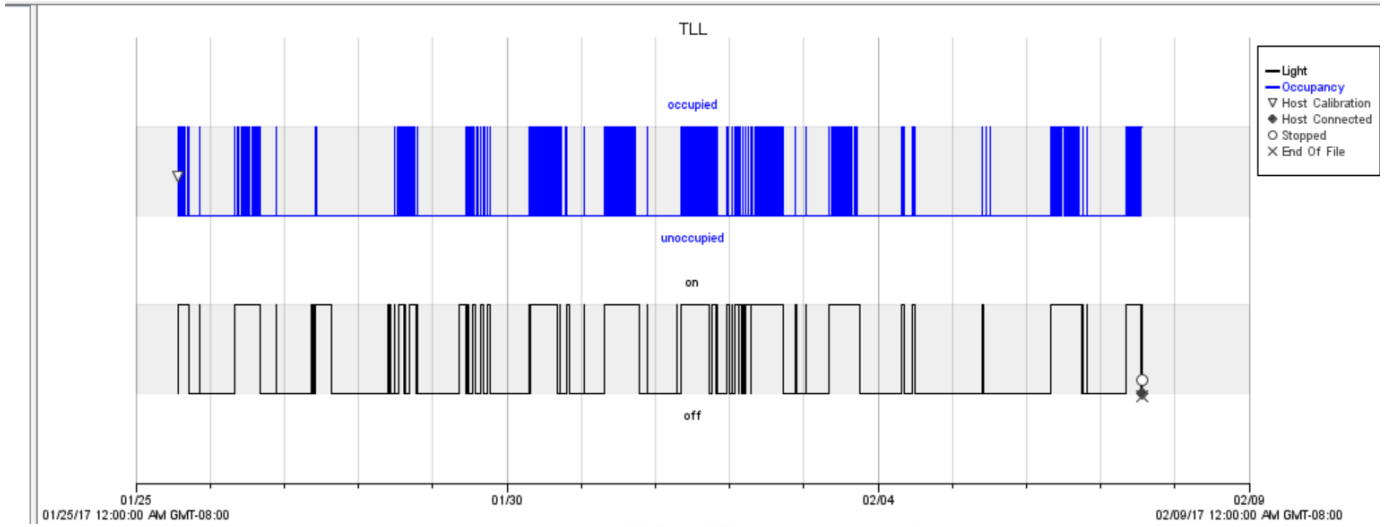
Automatic lighting controls

- Verify occupancy/vacancy sensors working correctly (sampling OK)
- Identify areas that could benefit from occupancy sensor or daylight harvesting
- Verify exterior lighting controls function correctly



light/occupancy logger

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Lighting Control Schedules

- Verify lighting on/off schedules match occupancy. Set or adjust as appropriate.
  - Stand-alone control or BAS interface?
  - Correct time and day?
  - Overrides?
  - Override length?
  - All lights controlled?

Lighting control panel

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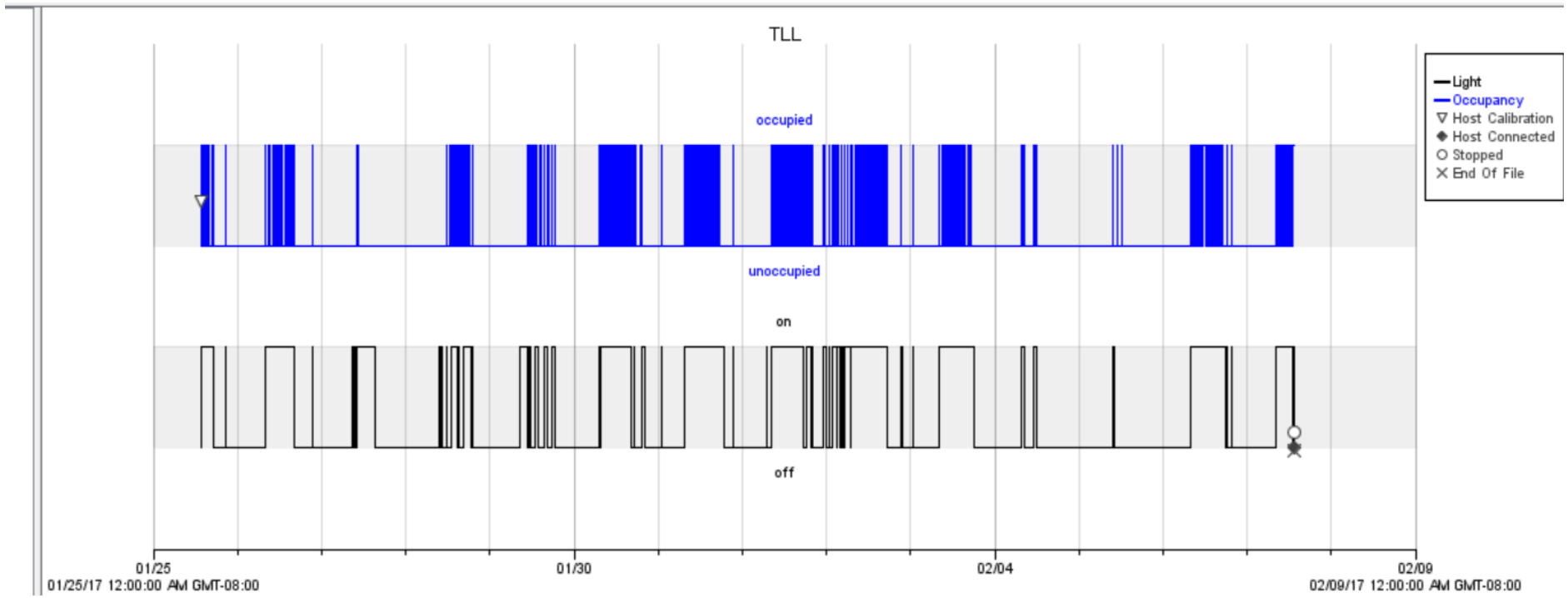
Light/Occupancy Logger Data



Does lighting system operation match occupancy?

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Lighting Maintenance

- Identify inefficient lighting equipment
  - Incandescent or metal halide fixtures
  - Fluorescent fixtures
  - Magnetic ballasts

Ballast checker

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Domestic Hot Water Systems

- Measure hot water supply temperature
  - Adjust setpoint for occupancy and use if appropriate
  - Seattle Plumbing Code 407.3 maximum hot water temperature to public lavatories is 120F
- Review circulation pump controls
  - Set or adjust as appropriate
  - No controls, integral control or BAS?

Control by BAS

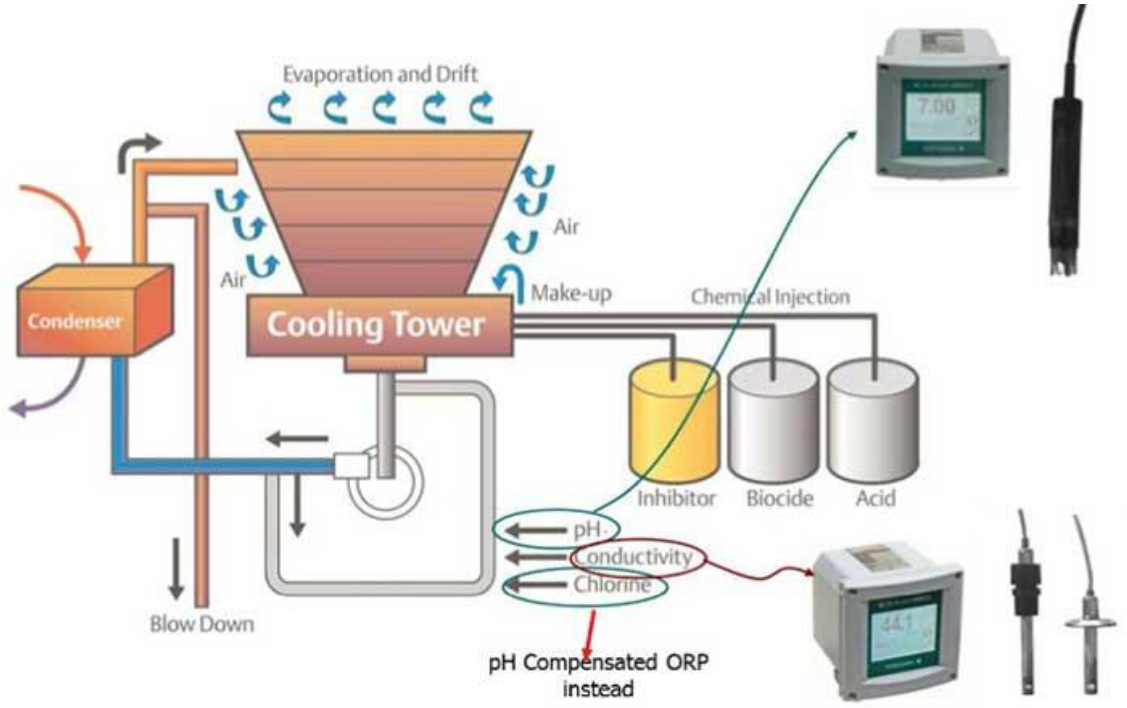
No control

Integral control

Water Usage - Ultrasonic Flow Meters

Water Usage – Cooling Towers

- Verify conductivity meter used to control blowdown is calibrated and functioning properly
  - Measure sump conductivity
  - Calibrate water treatment controller



Water Usage – Irrigation Systems

- Irrigated area >500 ft2
  - Review irrigation schedule for improvements
- Verify irrigation sensors are functioning properly
  - Locate rain sensor. Override irrigation zone you can see and activate sensor
  - Test continuity
  - Adjust, calibrate or repair/replace as required

Rain sensor/switch

Water Usage – Water Features

- Review water feature schedules
  - Set to shut-down during night time or unoccupied periods where appropriate

Water Usage – Maintenance, Cleaning & Repair

- Check irrigation system for leaks, overspray, broken heads, plugged nozzles or other operational problems
  - Adjust and repair as appropriate

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Water Usage – Maintenance, Cleaning & Repair

- Check hands free sensor-activated plumbing fixtures for proper operation
- Check water flow rate for fixtures
  - Recommend low-flow fixture or aerator replacement if appropriate
  - 2015 Seattle Plumbing Code Maximum Water Consumption
    - 0.25 GPM metered public faucets
    - 0.5 GPM public lavatories
    - 2.2 GPM private lavatories
    - 2.5 GPM kitchen faucet
    - 2.5 GPM shower head
  - Evaluate cooling towers for leaks and excess water consumption

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Building Envelope: Maintenance, Cleaning, Repair

- Check for unsealed penetrations that allow for entry of air or water
- Check for missing weather-stripping at doors & windows
- Check elevator shaft dampers- stuck open or leaky
- Identify uninsulated attic areas or insulation damage
- Identify any significant duct leakage (disconnected ducting or holes)

Gaps under doorways

Failed roof insulation

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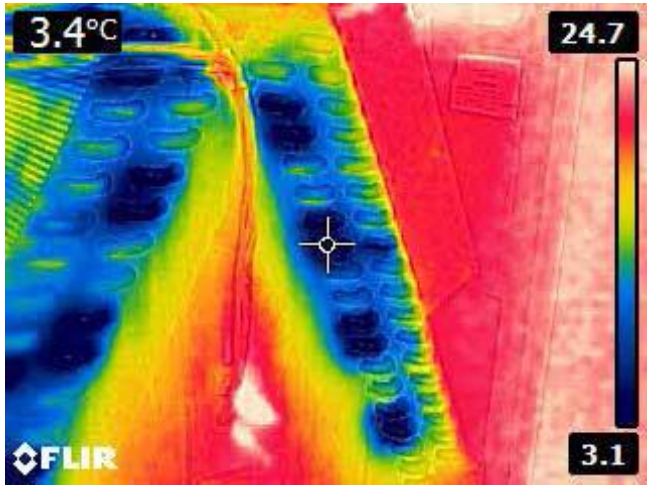
Thermography - Benefits

- Non-invasive
- Saves time/money
- Easy to use
- Broad range of applications: Building envelope, plumbing, electrical
- See the full picture
- Verify and/or pinpoint issues
- Identify minor faults early, before they grow



Source: FLIR

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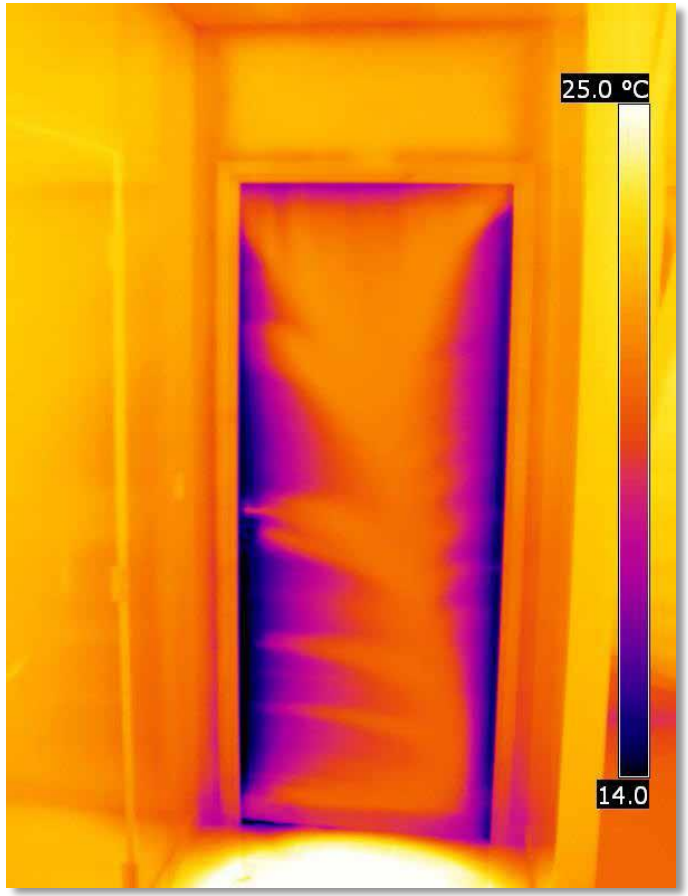
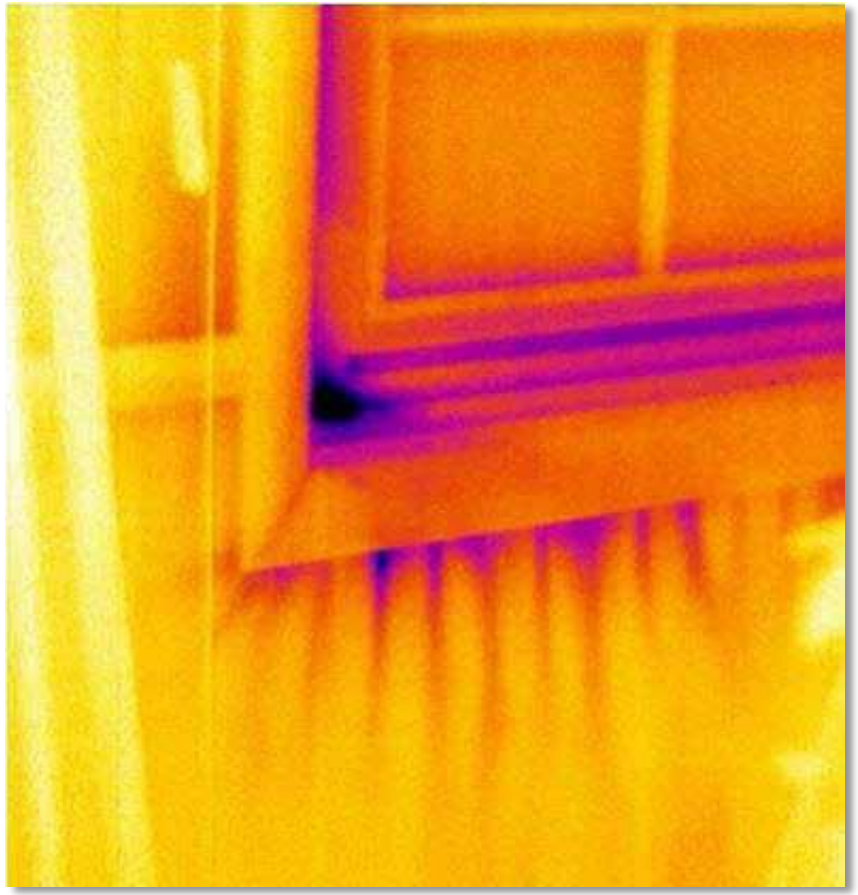
Thermography - Applications

- Building Envelope
- Plumbing
- HVAC
- Electrical
- More!

Thermal Envelope Applications





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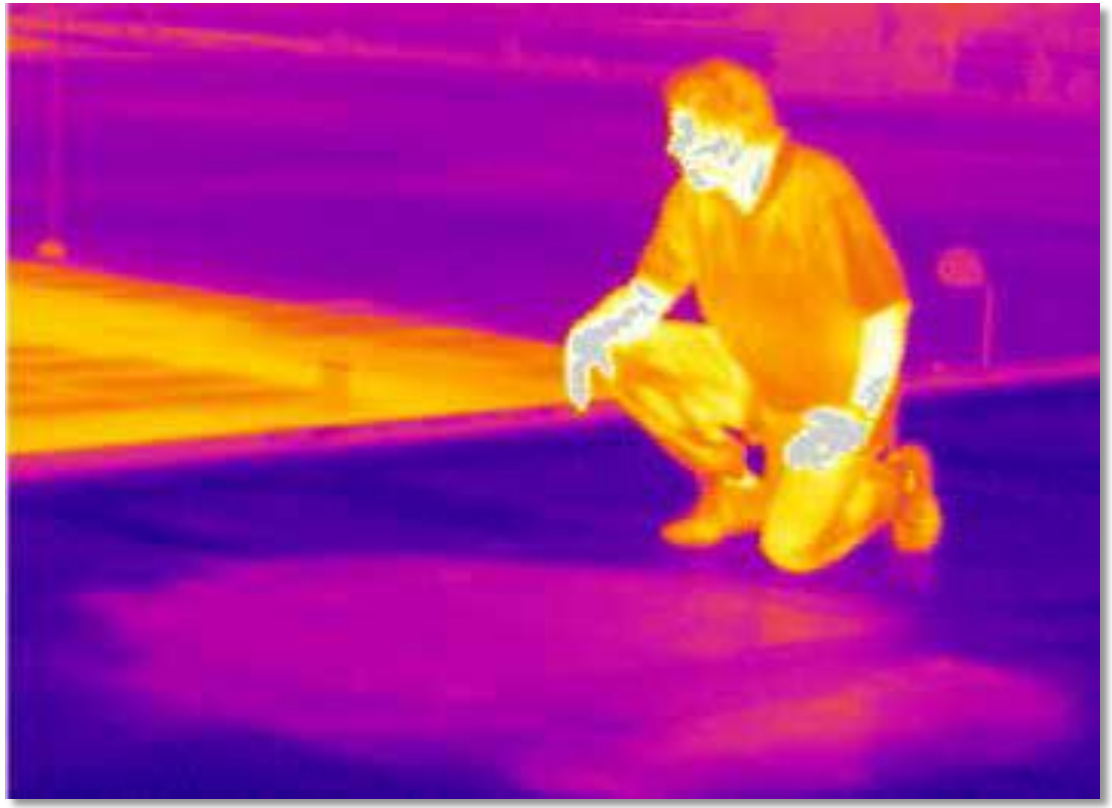
Thermal Envelope Applications

- Roof moisture – test at night after a warm day



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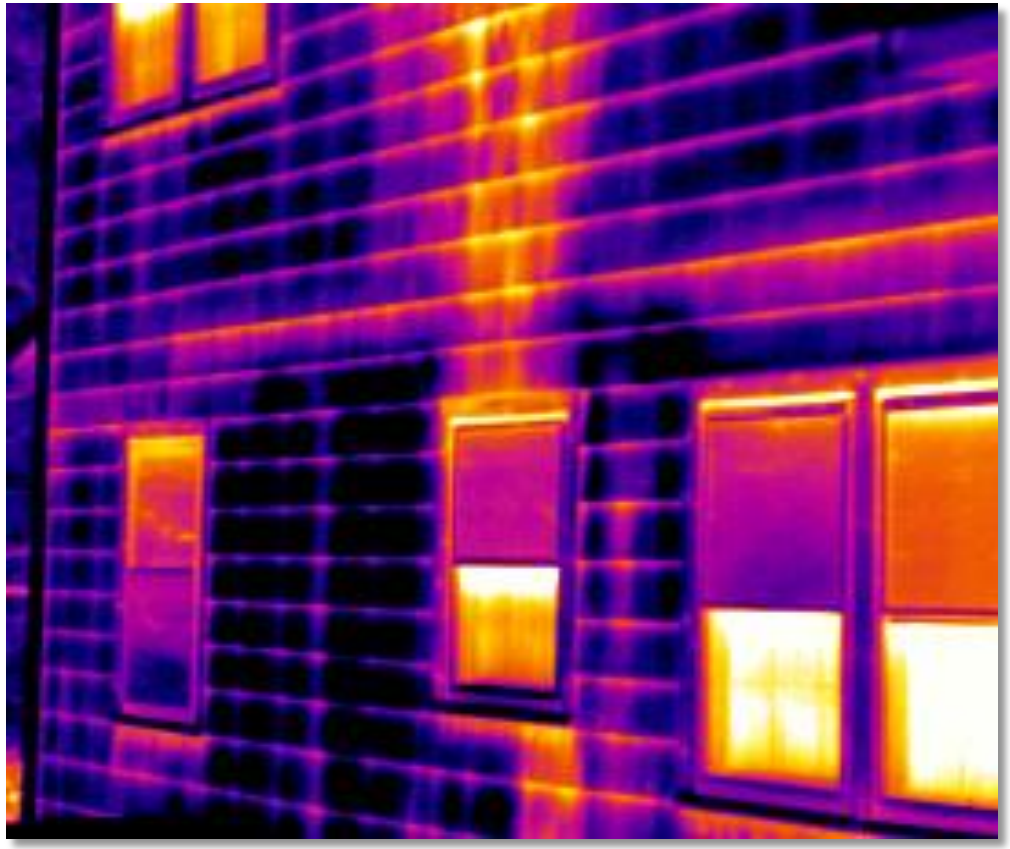
Thermal Envelope Applications

- Water leak in wall



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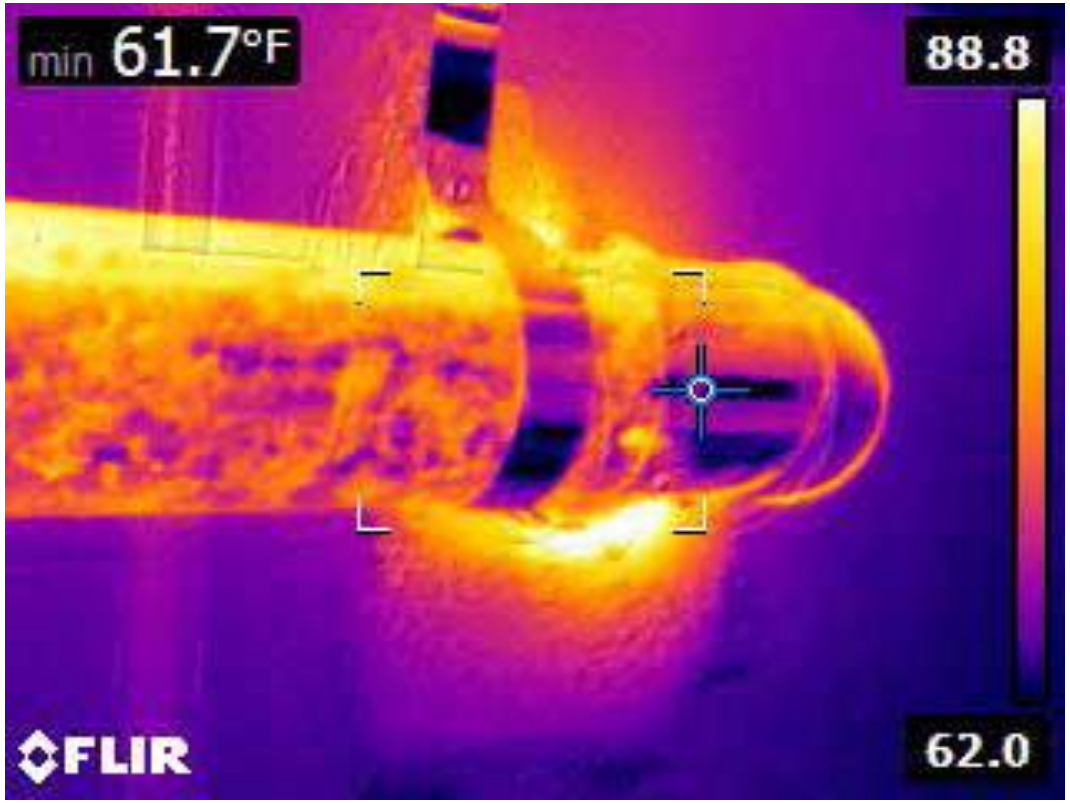
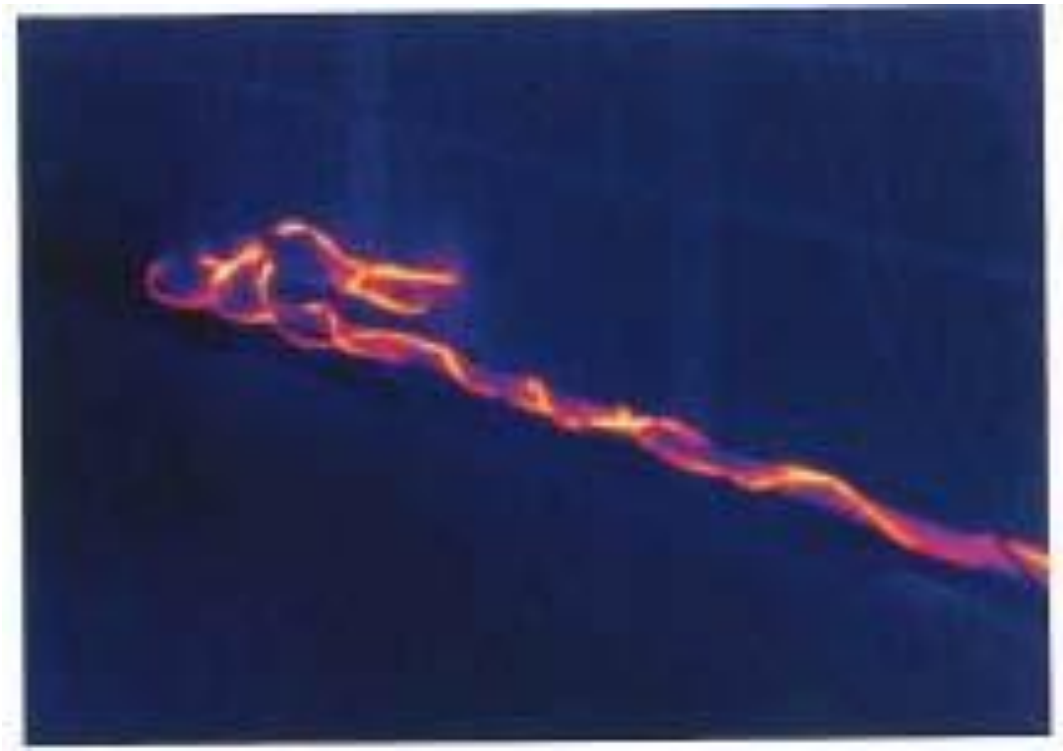
Plumbing



Source: FLIR

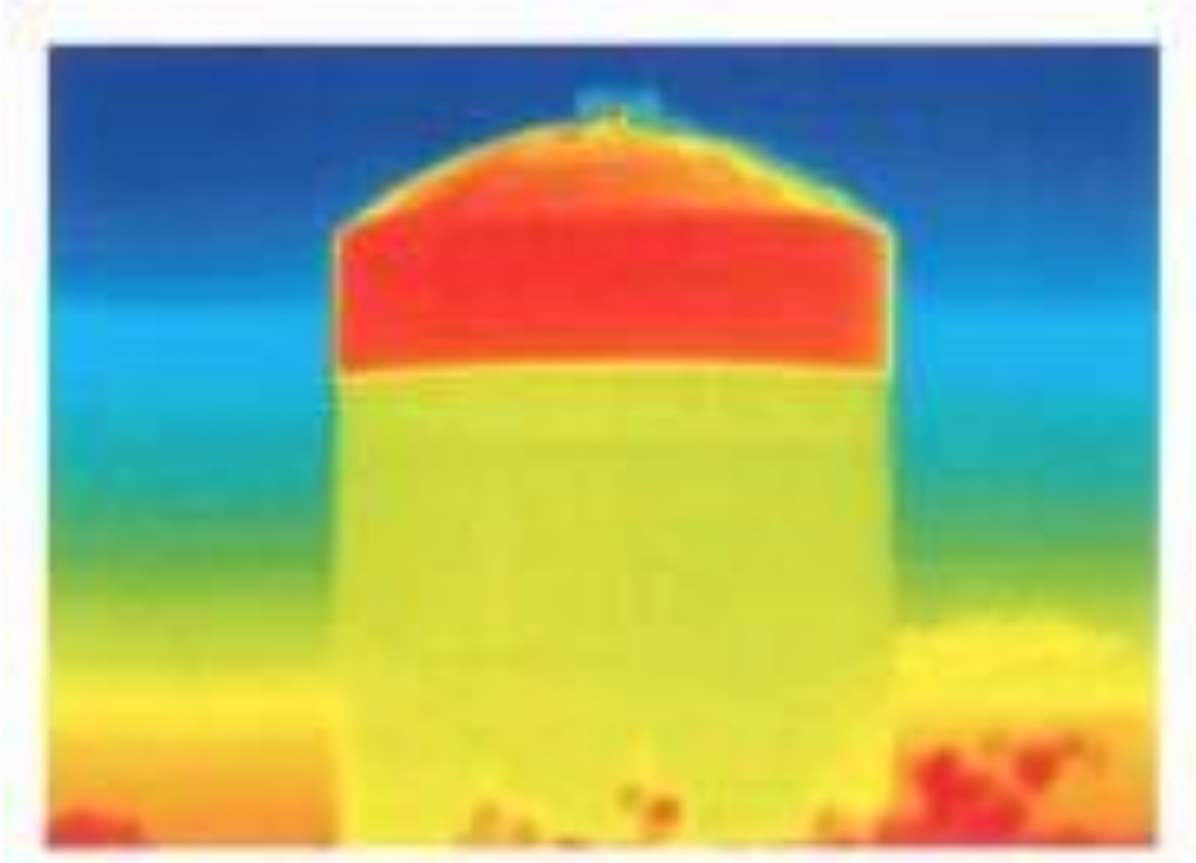
Plumbing

- Heating wire on outdoor water line



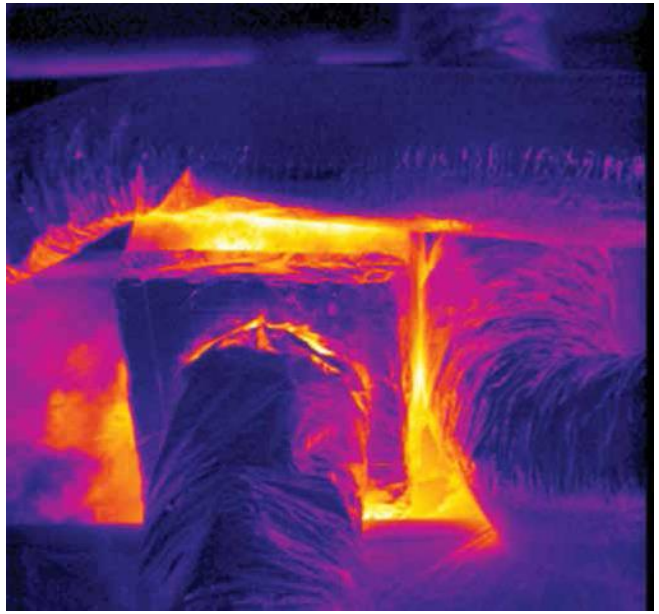
Source: Fluke

Tank levels



Source: Fluke

HVAC Applications



Source: FLIR

- Locate misrouted and leaking ducts
- See electrical or mechanical HVAC system faults
- Confirm the source of energy losses
- Find missing insulation
- Discover AC condensate leaks

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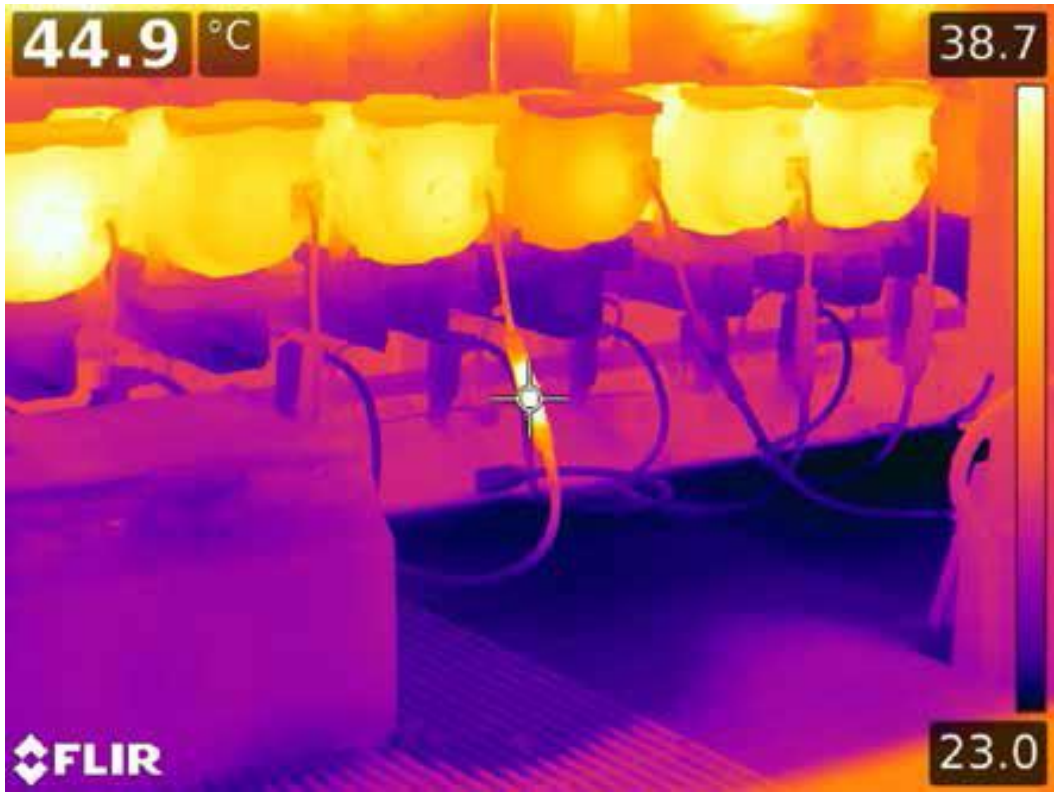
HVAC Applications

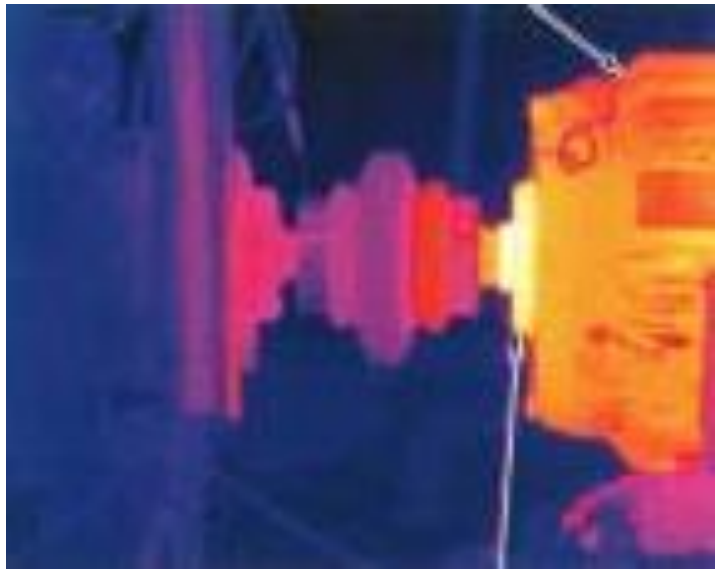
- Failing connector on a motor



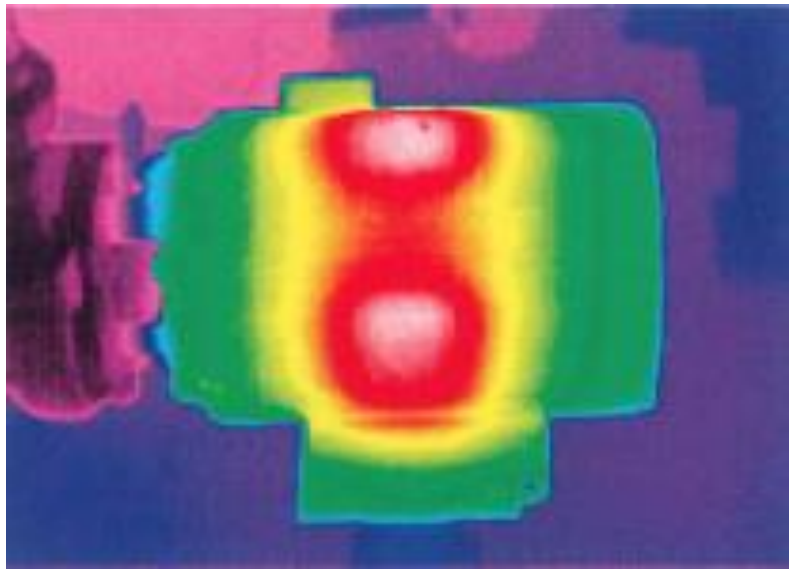
Source: FLIR

HVAC Applications

- Motor bearing warmer than casing could be a sign of a problem

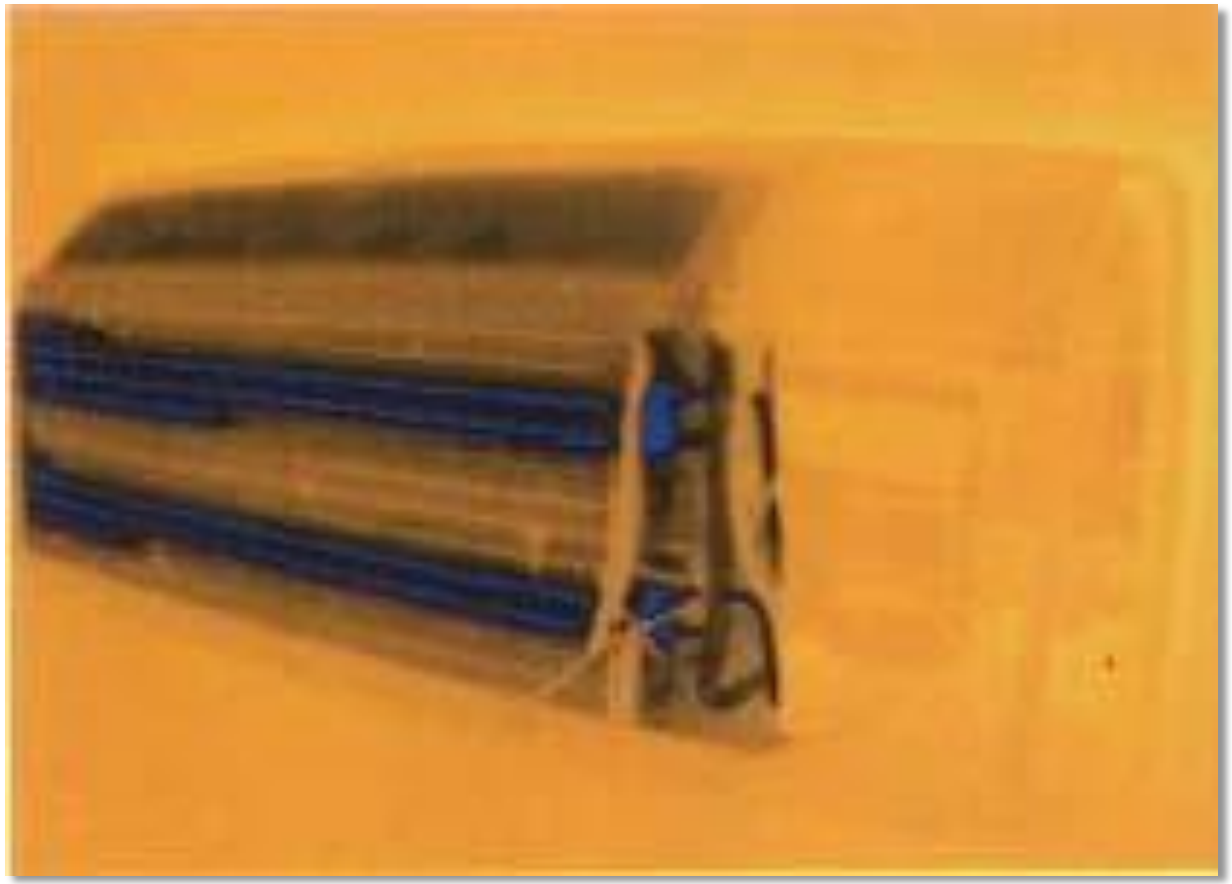


Normally operating pump motor (uniform thermal signature)



Source: Fluke

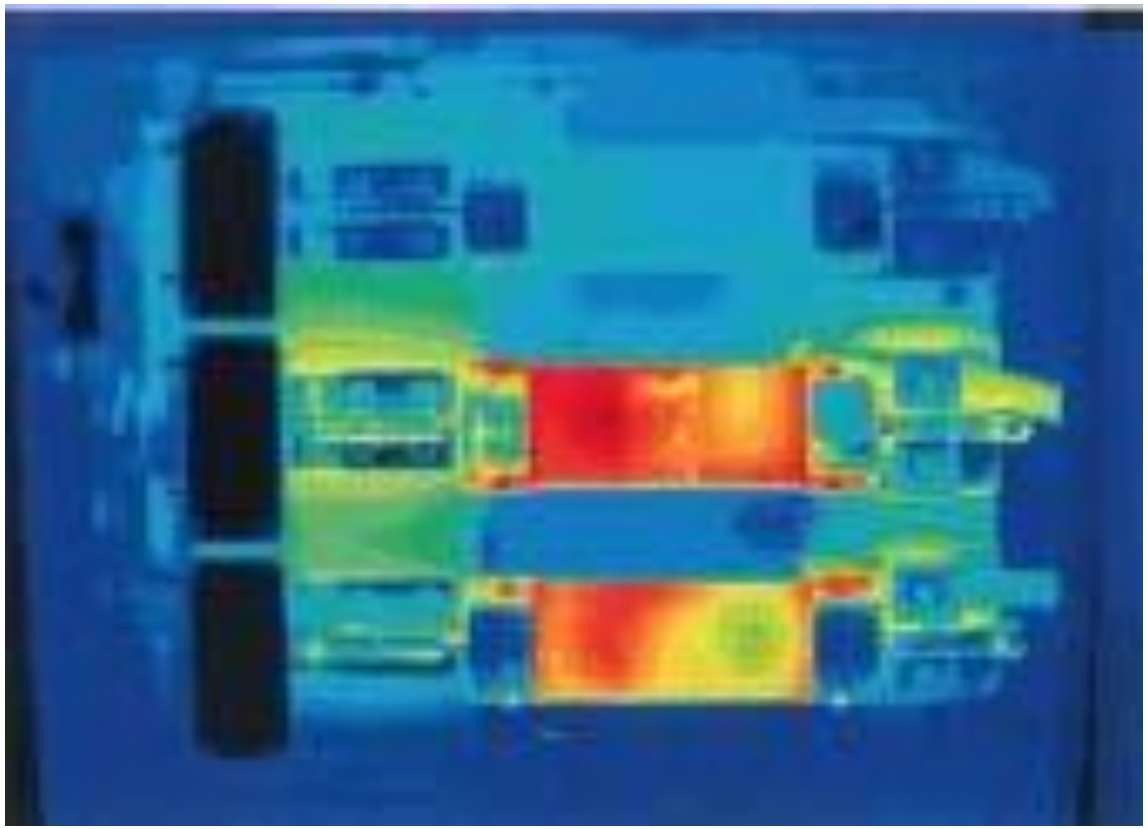
HVAC Applications



Source: Fluke

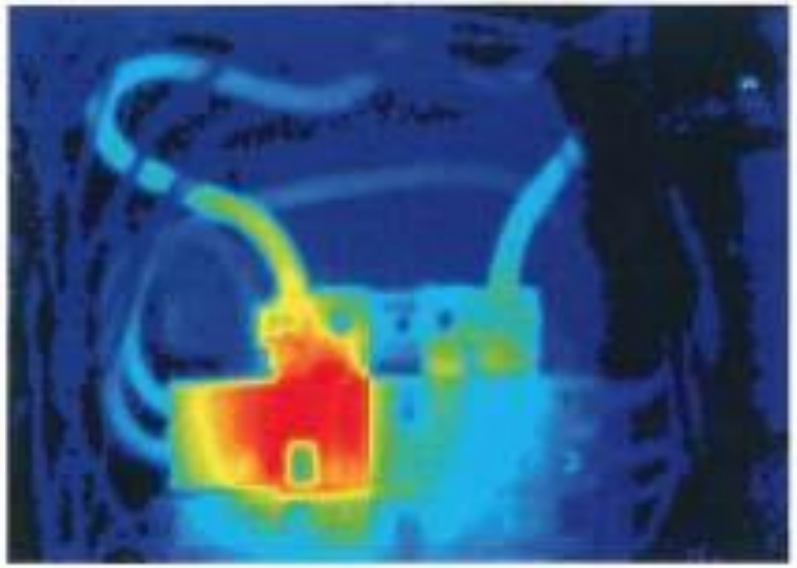
Electrical Applications

Hot spot doesn't always indicate the primary problem (blown fuse)



Source: Fluke

Electrical Applications



Source: Fluke

Review

- Building re-tuning is a systematic process to identify and correct no/low cost operational problems that lead to energy waste
- Major focus areas are HVAC, Lighting, Domestic Hot Water, Water Usage, & Building Envelope
- Building re-tuning is observation and data driven

QUESTIONS ?

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time for …

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