BUILDINGENERGY BOSTON

What We Wish Everyone Knew: Using Commissioning Discoveries to Make Buildings Better

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Curated by Fred Davis (Fred Davis Corp.) and Chloe Moucachen (Northeastern)

Northeast Sustainable Energy Association (NESEA) | March 20, 2024

Buildings are starting out compromised

- Some common issues – some more preventable than others
- See these on a significant percentage of projects
- How do we minimize this at scale?

https://commons.wikimedia.org/wiki/File:Leaning_Tower_of_Pisa_%284%29.jpg

Learning Objectives

1. Discover how commissioning supports the design and construction process, and use that understanding to improve how different parties interact and communicate with the construction team.

2. Leverage insights from the most common design issues encountered to improve on mechanical, electrical and plumbing designs

3. Identify what to look for and how to avoid some of the less common, but more significant design issues discovered on past projects to avoid them in the future

4. Understand key points where owner, commissioning agent and designer involvement in a project can make the difference between successes and failure

Who We Are

LOU VOGEL, PE, LEED AP, CCP
DIRECTOR OF ENGINEERING

NATE GOODELL, PE, CCP, EBCP
SENIOR ENGINEER

Who Are You!

Who is in the audience today?

- Engineers
- Architects
- Owners and Maintenance providers
- Contractors
- Sustainability consultants
- Other?

Presentation Organization

Intro

- Defining the problem

Lighting Controls

- Problems and Solutions
- Example

Plumbing Systems

- Problems and Solutions
- Example

Mechanical + Control Systems

- Problems and Solutions
- Example

Conclusions & Questions

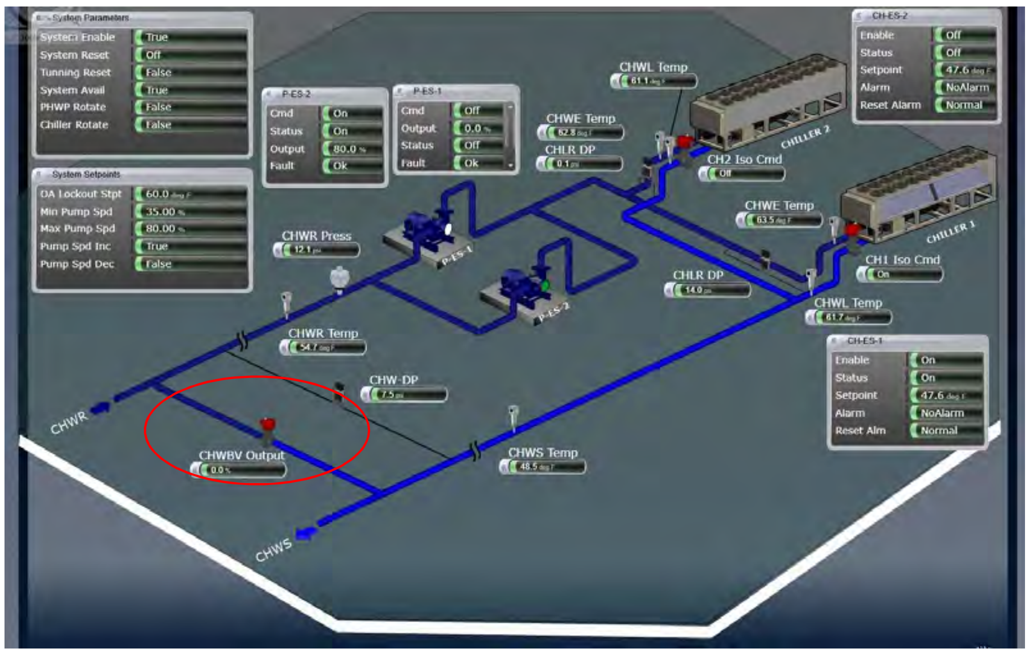
Taitem

DEFINING THE PROBLEM:

3:30

Buildings are starting out already compromised

What do we mean by this?

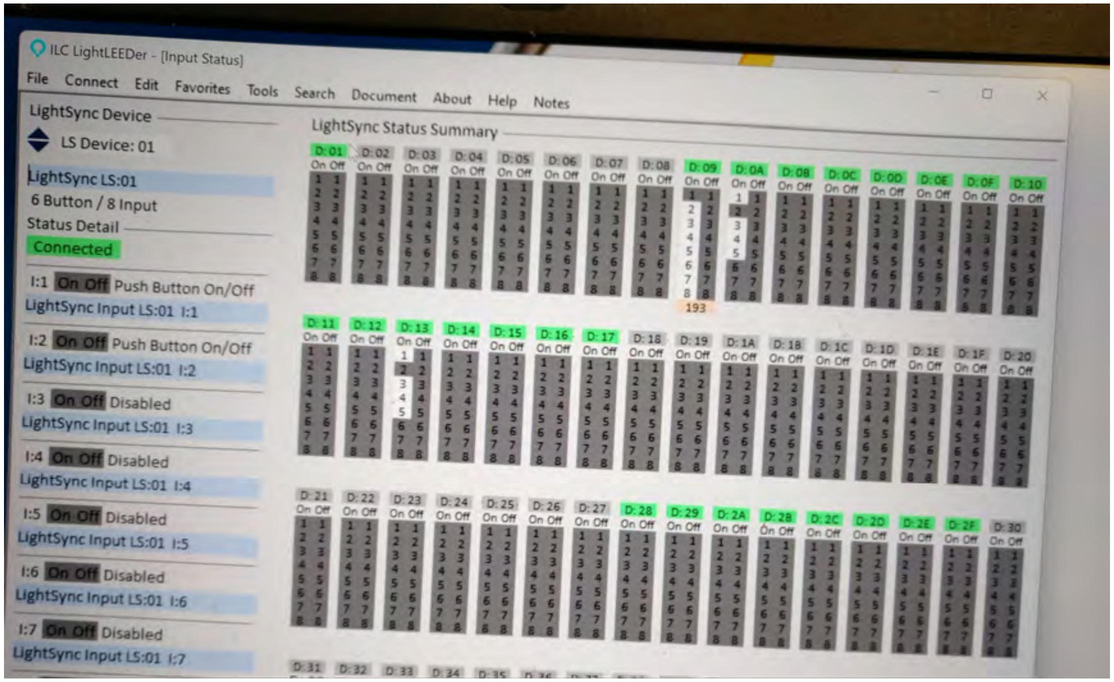


6:00

Lighting Controls

Lighting Controls

- Increasingly sophisticated & networked
  - More capabilities!



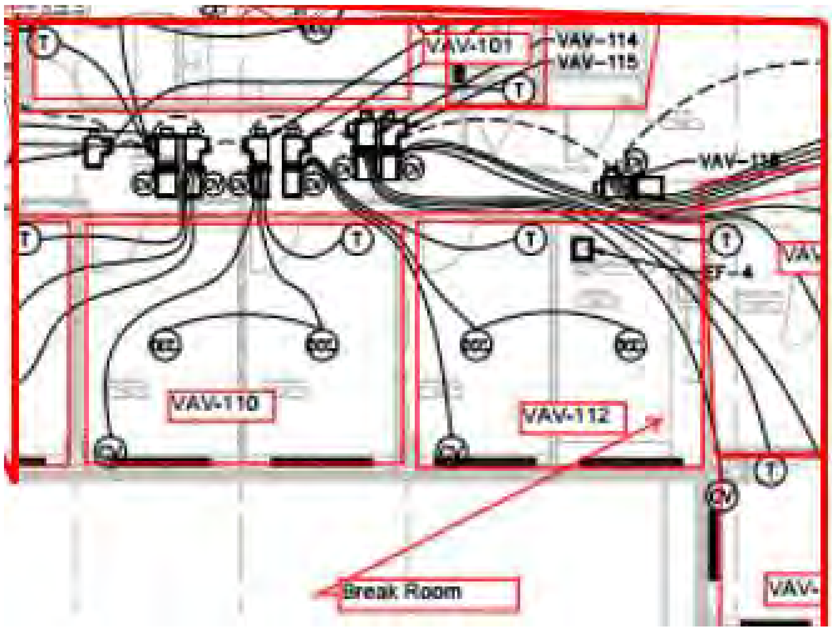
- But…does complicated = better or more energy efficient?

Lighting Controls

- What do we need to do to make these work?

- Clear upfront understanding of owners goals, and local requirements
- Clear basis of design/intended sequence
- Work closely with the system vendor
- Substitutions may not be practical
- Include training in the specs for the owner
    - And tools to adjust, and follow up training

Occupancy and HVAC integrations



Lighting control zones vs. VAV thermal zoning

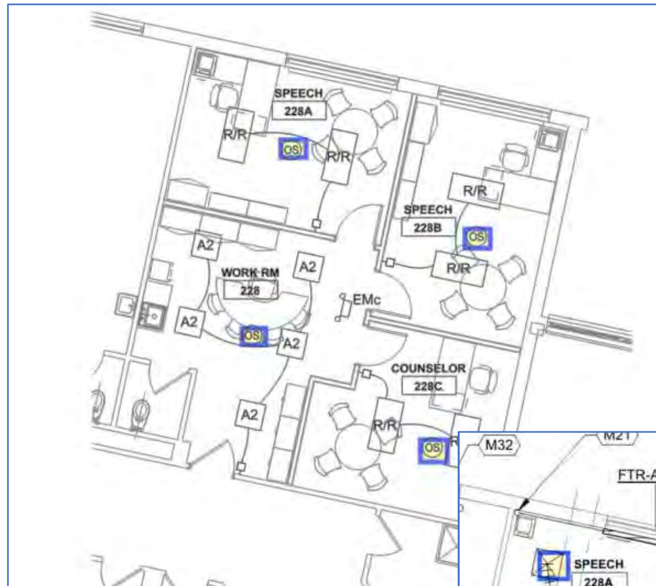
- Issue: Morning Warm up, Nuisance Triggers, Controls Integration, **and what about zones with two rooms?**

Suggestions:

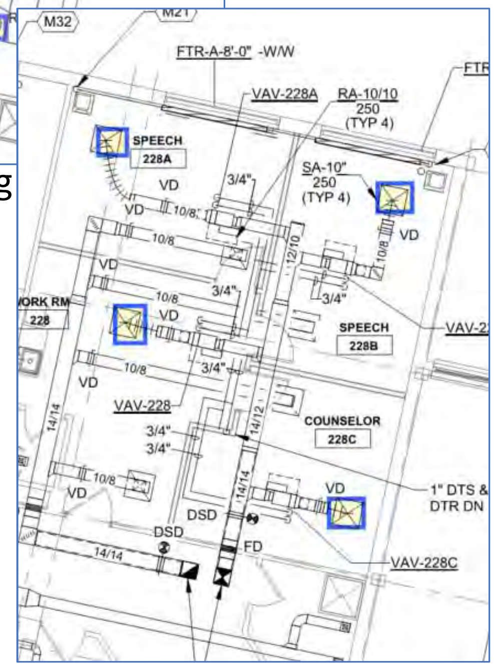
Scheduled pre-warm,
Reduced daytime setbacks
Primarily use to control ventilation

Installation Issues:

- Sensor locations:
  - Proximity to HVAC: 50%
  - Open door/nuisance triggers: 15%
  - Unexpected Furnishings: 10%
- Mechanical vs Digital Switches: 15-20%
- Failure to Program: 75%
- Bonus: Small movement vs. large movement sensors



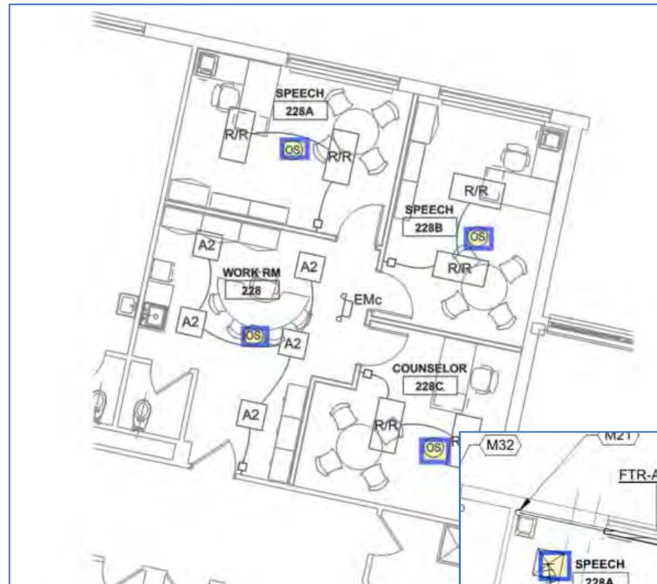
Lighting Controls drawing



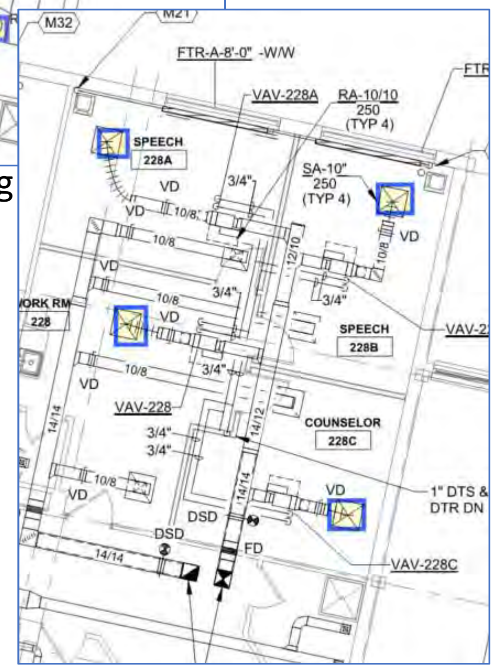
Ductwork (diffusers) drawing

Installation Solutions:

- Sensor locations:
  - 5-8’ from HVAC,
  - 12’ from other ultrasonic sensors
  - Mask sensors as needed
  - Predict furniture/user locations (outlets and ethernet)
- Use digital touch switches with controllers
- Owners/Users – we need your feedback!
- Try to have visually different sensors



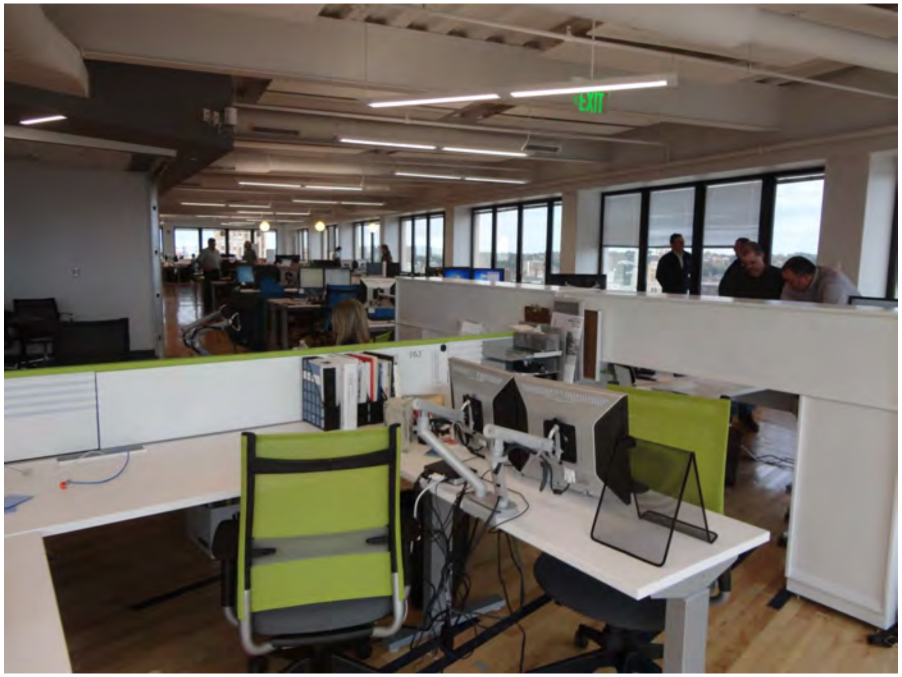
Lighting Controls drawing



Ductwork (diffusers) drawing

Daylight Harvesting

- Non-trivial to install and configure correctly: 90%+ failure rate
  - Multiple projects have reported that they won't do it again after bad experiences



- Solutions?
  - Still working on solutions other than ensuring testing, training and calibration are well defined in scope


15:00
Lighting Control
EXAMPLE

Vacancy sensor lighting controls

- Ceiling dual tech occupancy/vacancy sensor, with wall mounted on/off switch.
- Requested sequence:
  - Lights are turned on manually,
  - Auto off after 10 minutes
  - Occupants can manually turn off sooner

The Issue(s):

- Sensor powered by wall switch
- System left in default occupancy mode
- Ceiling sensor located right by HVAC diffuser
- Mechanical (not digital) on/off switch used

- Solutions:
  - controllable relay, permanent power to sensor, careful coordination of sensor placement

Plumbing

Heat Pump DHW

Local systems

CONSIDERATIONS

- Hybrid Heat Pump operation modes
- Return water temperatures/expected loads
- Supply water setpoints

DESIGN CONSIDERATIONS

- Peak demand charges
- source of air to transfer heat from

Suggestions:

- Specify the desired mode on drawings
- Design for minimal recirculation load, minimum supply and return water temperatures.
- ducted air kits,
- pro/con analysis of demand charges and coincident peaks

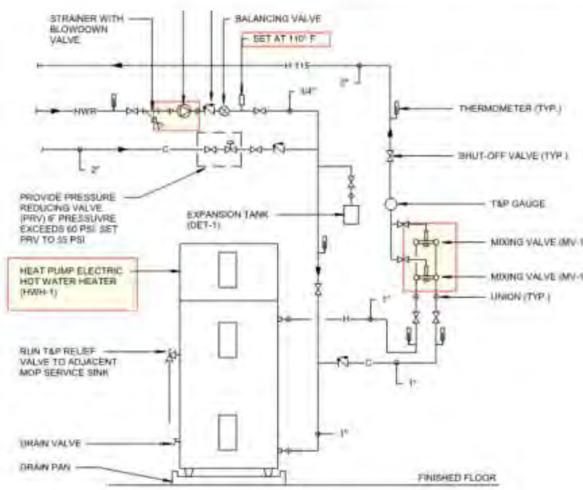
Change Mode of Operation

Press the "MODE" button to select operating mode.

Modes of Operation

- Energy Saver
- High Demand
- Heat Pump
- Electric
- Vacation

Mode	Efficiency	Recovery
Electric	Very Low	Fast
Heat Pump	High	Very Slow
High Demand	Low.	Very Fast
Energy Saver	Very High.	Fast
Vacation	Very High	None



NOTES:

1. COORDINATE WITH ELECTRICAL CONTRACTOR FOR EXACT REQUIREMENTS.
2. PROVIDE INLET AND OUTLET OUTDOOR AIR KIT.
3. PROVIDE 24" DEEP HEAT TRAP ON HOT WATER SUPPLY.
4. PROVIDE DRAIN PAN UNDER HEATER.
5. COORDINATE WITH MECHANICAL CONTRACTOR (INLET/OUTLET DUCT CONNECTIONS).
6. STORAGE TEMPERATURE SHALL BE 140 F.
7. PROVIDE PRV ON COLD WATER INLET TO HEATER IF PRESSURE EXCEEDS 55 PSI.

9 HEAT PUMP HOT WATER HEATER

Heat Pump DHW

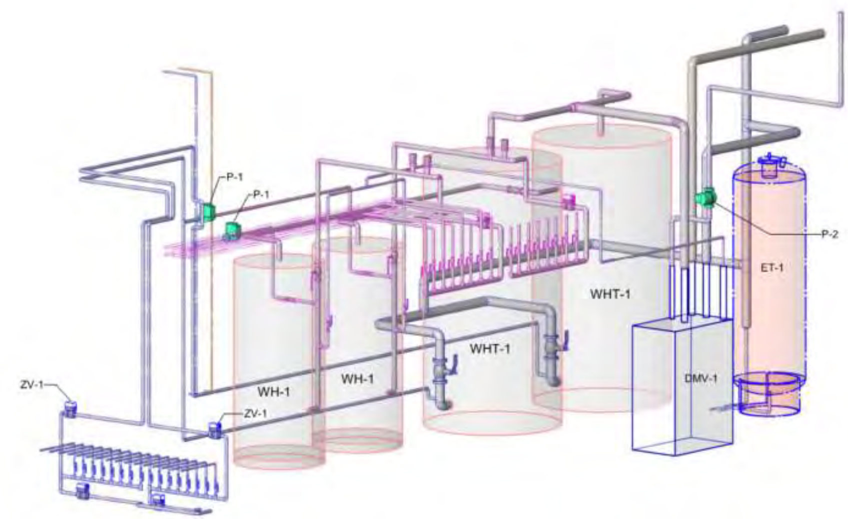
Central HP systems

DESIGN CONSIDERATIONS

- Efficiency & return water temperatures (recirc?)
- Stratification and storage
- Lower max temperature
- Backup systems and how they integrate
- Unit specific sequences and operating characteristics

Suggestions:

- Careful design
- coordination with manufacturer and installer
- extra testing and monitoring

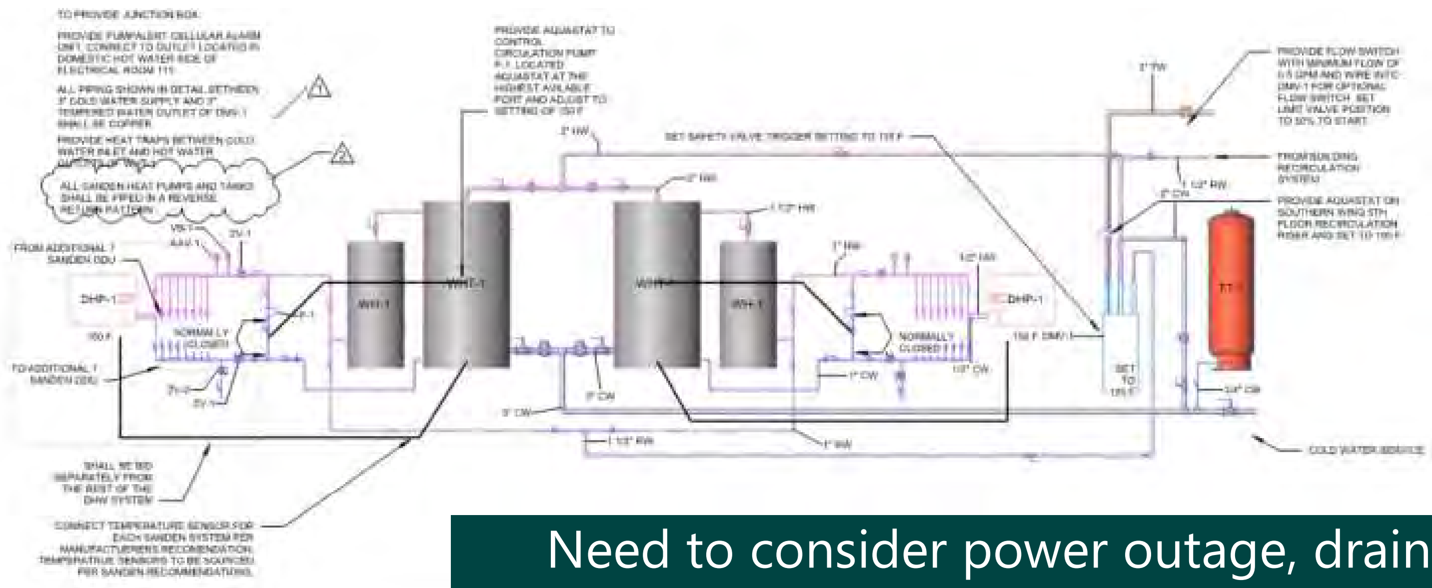


Heat Pump DHW – CO2 based

22:00

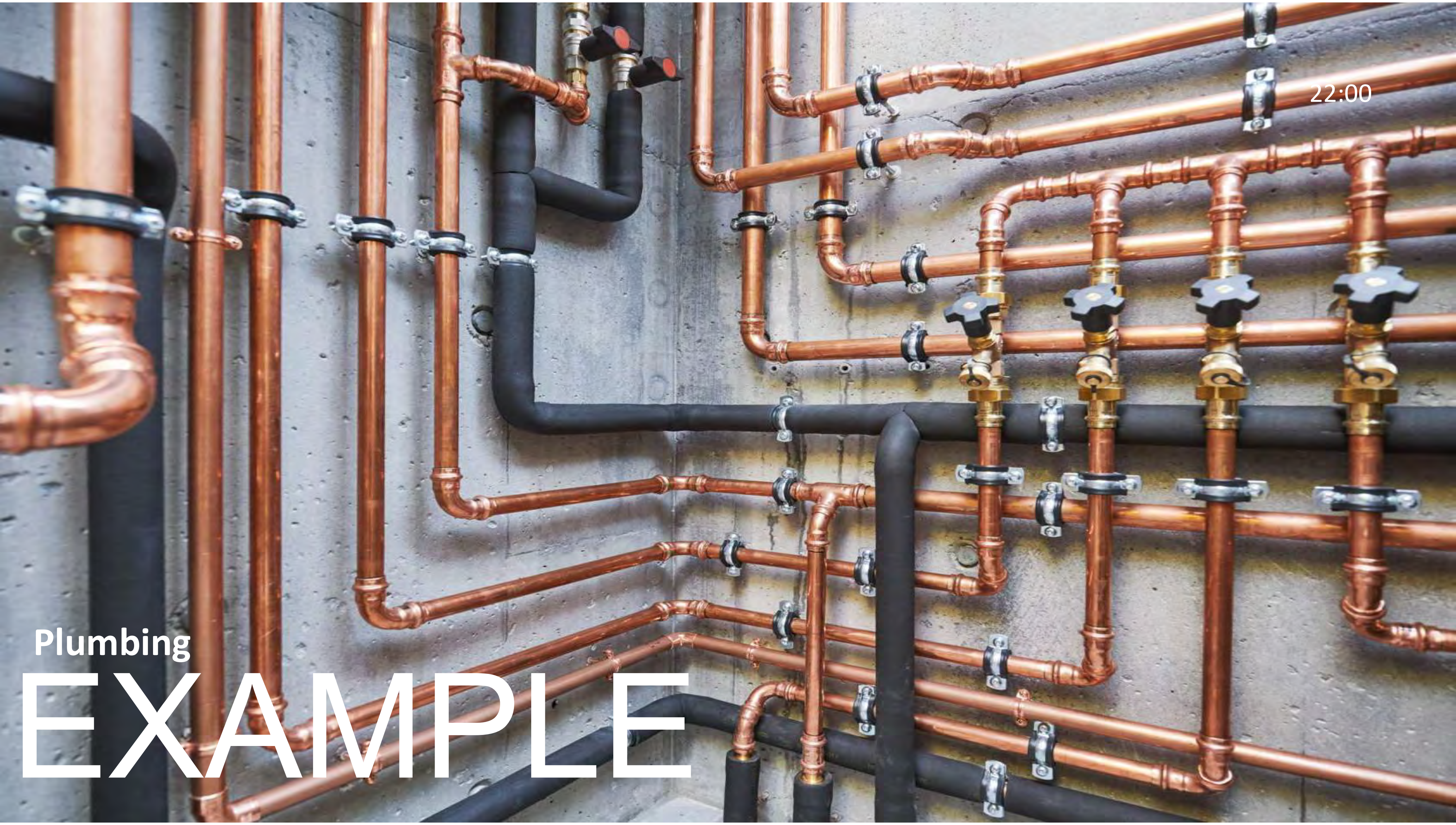
FREEZE PROTECTION

- Consideration with newer heat pump systems – exterior potable water



2 WATER HEATER SCHEMATIC
1/4" = 1'-0"

Need to consider power outage, drainback systems



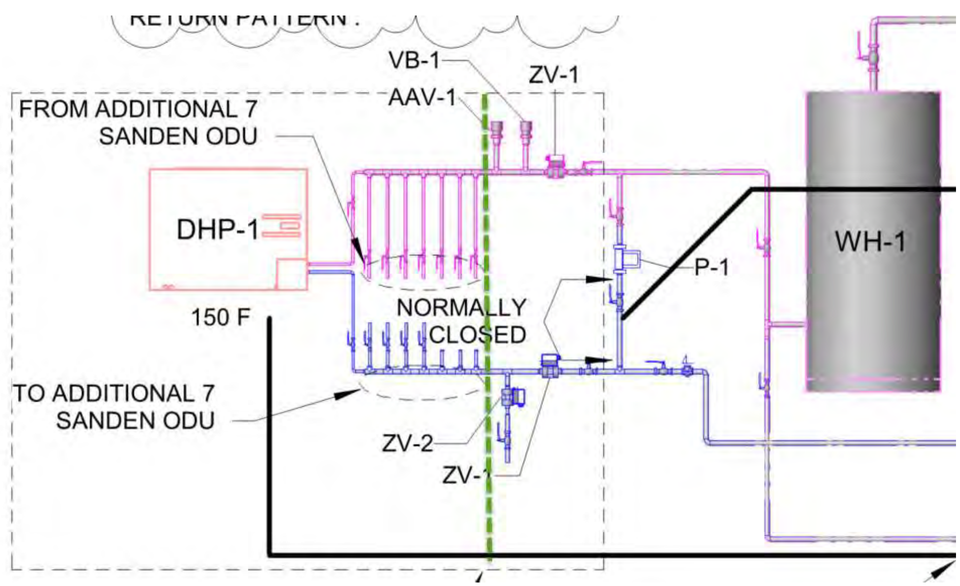
22:00

Plumbing

EXAMPLE

Auto-drainback freeze protection sequence

- How it works:
  - Two sets of valve, with a spring return (normally open/normally closed)
  - When power is lost, a set of valves that are normally powered open where the water leaves the building to go to the heat pump outdoor units automatically close.
  - Two other valves going to drains that are normally closed open at the same time, draining the outdoor portion of the system.
  - This requires careful installation and slope of the outdoor piping.

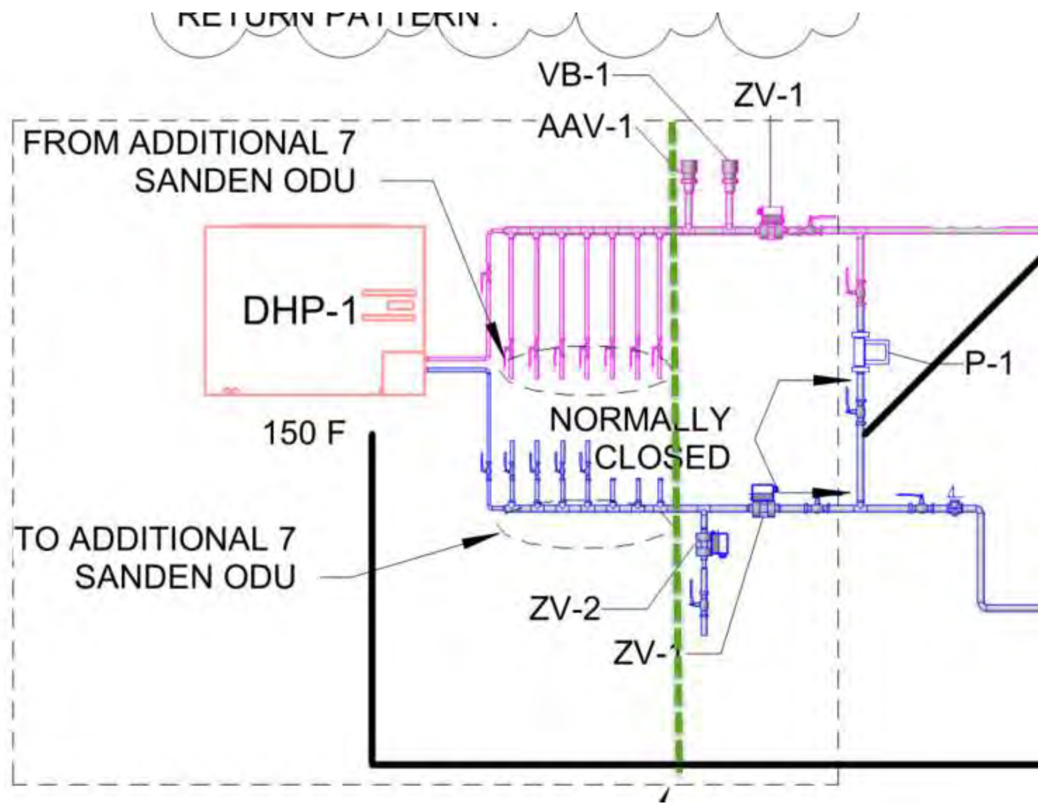


Auto-drainback freeze protection sequence

23:30

- What issues would you expect?
  - Water caught in the system?
  - Incorrectly installed valves?
  - Other?

- The drainage of the system actually worked great…



Main issue was actually on refill of the system

- When power was restored, the valves all reverted, trapping a large amount of air in the system.
- More than could be handled by the automatic air vent
- Heat pumps were getting air bound and faulting out in error.

Solutions?

SOLUTION

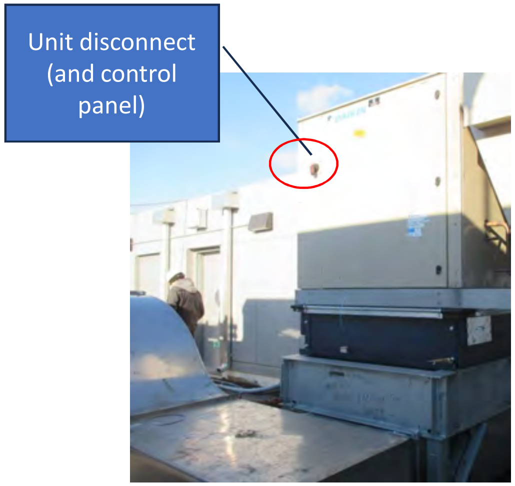
- Customized delay offsets in some of the valves to purge and fill system automatically

→Water fully fills the system and starts to drain before upper vent valve closes

MECHANICAL

Maintenance Access

- Issues:
  - Busy Ceilings – Can't find/access equipment: 60%+
  - Solution: Identification Stickers, Access Doors
  - High Roof Curbs/Ductwork Obstructing Equipment Access: 30-40%
  - Solution: Catwalks and Duct Bridges
  - Above Ceiling Clearances for Controls, Filters, Replaceable Components, etc.: 30%
  - Solution: Build Clearances into design as graphic elements on plans, access doors in ceilings.



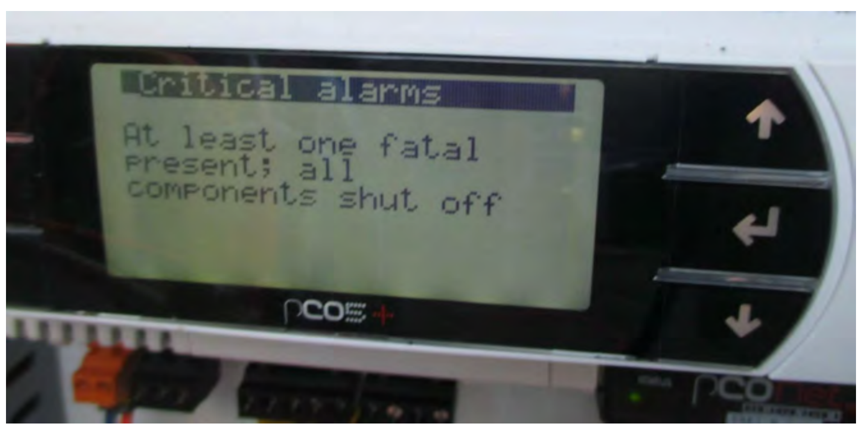
27:00

Substitutions and Value Engineering (VE)

- 40-50% of substitutions we see introduce some new issue
  - When can you do this, when will it cause issues
    - Be wary of unanticipated side effects
  - Areas of concern:
    - Accessories
    - Integration with other systems, particularly controls
    - Technologies and limits on performance
- Almost 100% of VE changes caused issues
  - What should owners know?
- Note – not always avoidable.

Substitutions and Value Engineering (VE)

- Solutions:
  - Investigate availability (lead times) and cost of major/critical units before bid
  - Avoid the temptation to defer design work assuming long lead times or project delays will give you time to work out details later
  - Consider including a clause in contracts allowing you to bill for extra time spent on design work due to changes from basis of design model



33:00

Considerations for Sizing

- Considerations for Sizing
  - Heating vs cooling & Oversizing: 20-30% or more of projects
    - Coil Selection
  - Availability of summer reheat (very common)
  - Peak Design Conditions
    - Are they really accurate?
    - What is the owners comfort level/primary concerns regarding temperature control?

40:00

Pet Peeves

- Unoccupied VAV operation: 90%+
  - What runs when a single space needs heat?
  - Does the entire system know its unoccupied?
  - Priority heating devices
- Zoning
  - IT closets need their own zone: 30%
  - Think for current use and schedules AND future modifications when grouping spaces
  - Large open spaces need a central control device [HPs especially]: 20-30%
- Freeze protection and safeties: 30%
  - Make sure these are thought through with new efficient systems
- Usable Thermostats and Schedule Controls: 60-90%
  - Interface that Owners/Users have has huge impact on how the system is used

Frequent Controls Issues

45:00

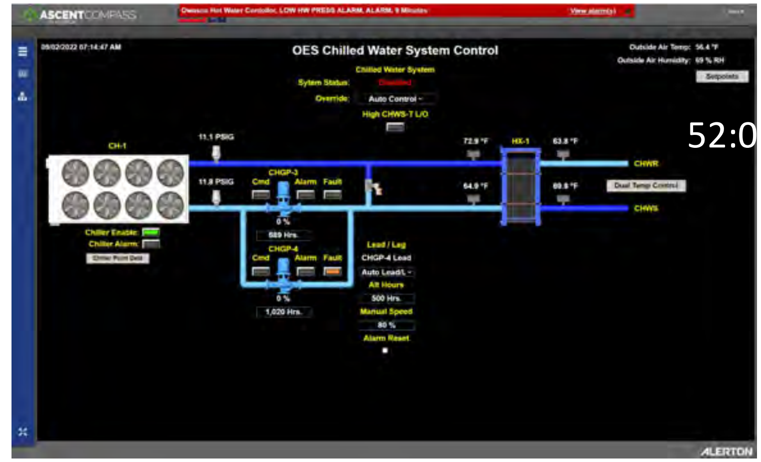
Controls Success = No Complaints (vs. efficiency/correct operation)

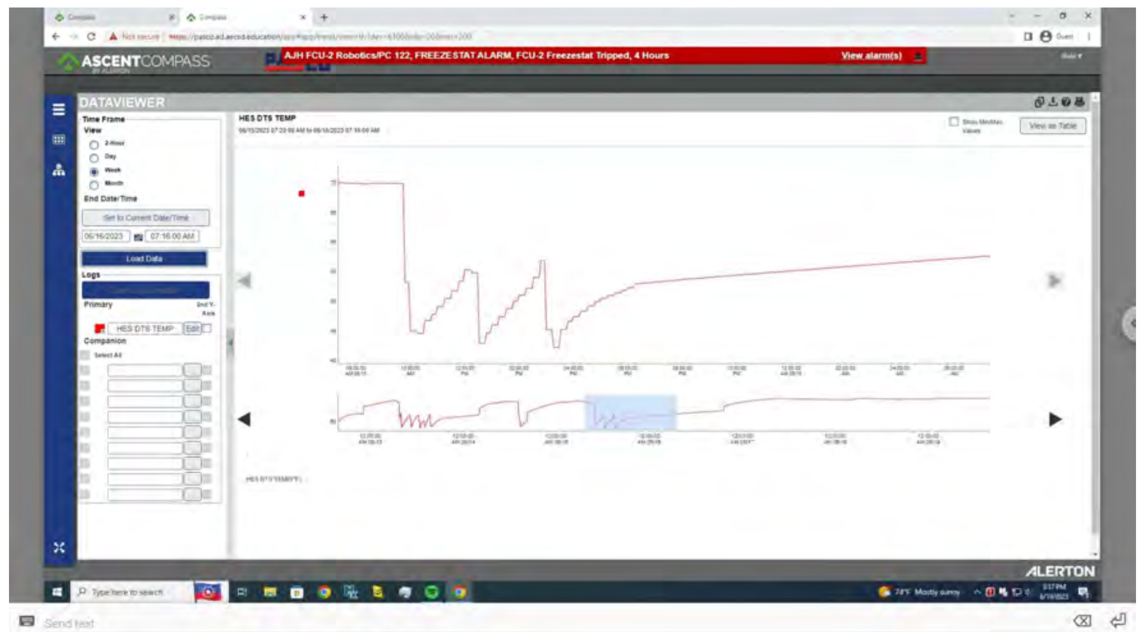
- Packaged controls vs. central BMS: 65%
- Control sequence extremes: 30%
  - Reliance on controls contractor VS packaged sequences VS over-constraining
  - Who owns what? 25%
- Coordination with TAB, startup, owners IT (and Cx of course)
  - Almost always see at least one coordination issues

Controls example: Chiller

- Packaged controls integration with BMS –
  - Chiller cycling – fixed supply water setpoint, enabled/disabled by BMS

- Solutions?





Frequent Controls Issues – Suggestions?

46:00

Controls Success = No Complaints (vs. efficiency/correct operation)

- Change the metric for success!
  - Dedicate resources for ongoing engineering and Cx support of efficiency and other controls goals
- Control sequences spell out key deliverables and efficiency goals (don't over constrain, but clearly define expected results)
- Bring in IT and other controls consultants in early
- Anecdotally, ways you can help controls contractors justify spending more time on a project up front work well
  - 'I have to do it, they are coming to test next week'
  - 'That's a little trickier to program, but it will be worth having for our service contract'

Mechanical/Controls

EXAMPLE

47:00

This Room!

- What potential issues have you noticed?
- What do you think might be causing those issues?
- Potential Solutions?

Conclusions

53:00

Lots of things go wrong during construction!

Recent project we worked on:

<u>New Construction, Multifamily Building</u>

All Electric, High Efficiency. Not a bad project!

Some of the issues we discovered:

- Heat Pumps
  - Leaks: 5-10%
  - Controls : 90% at some level
- ERVs
  - Incorrect units: Rare, 5%
  - Factory default controls: 80%+
- DHW System
  - Coordination between primary and backup system: 100%/TBD
  - Inaccurate submittal information: 10%
- Lighting Controls
  - Controls were not set up until after occupancy: 10%/60+% have setup related issues

All preventable, but some more easily than others…

COMMISSIONING AGENTS DON'T SOLVE EVERYTHING

We can be the eyes, ears and experience for an owner, but at the end of the day, all we can, and should, do is make suggestions.

We are just one part of a team that helps ensure the systems are operating correctly!

- Still need design engineer
- Still need owner involvement
- Need installers there to help us!
- Focused on larger systematic issues

54:00

HOW CAN WE USE THIS INFORMATION TO IMPROVE AS AN INDUSTRY?

What are your ideas?

QUESTIONS

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Taitem

Committed to high performance buildings...

Engineering excellence since 1989.

Taitem is a full-service consulting engineering firm whose projects include buildings in multiple sectors. During 30 years of continuous operation, Taitem has continued to expand its offerings in energy efficiency and net-zero energy, leading the market, while maintaining its commitment to its mission as reflected in its name, "Technology As If The Earth Mattered."

...and the people who depend on them

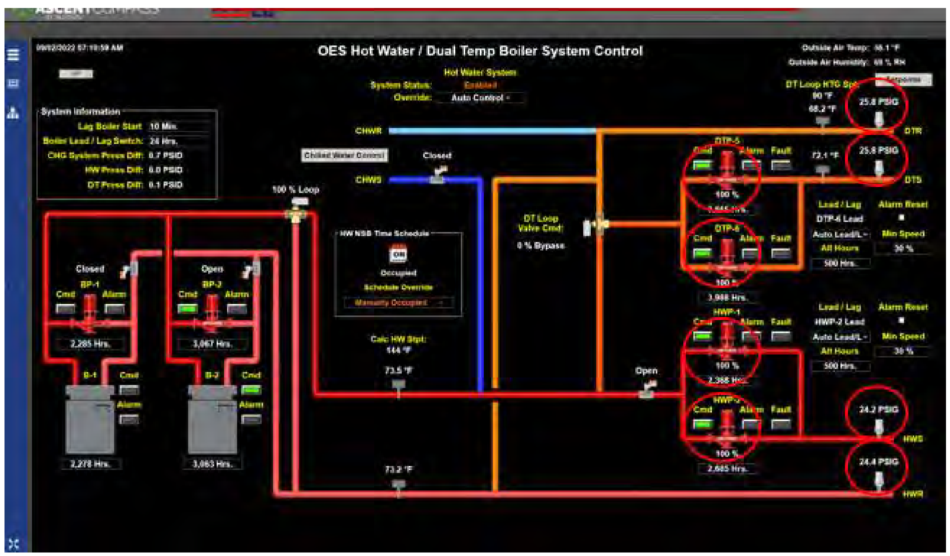
Taitem is a mission-driven firm, committed to the “triple bottom line” of people, planet, and prosperity. We are committed to creating a diverse and inclusive workplace.

Certified B-Corporation Taitem voluntarily meets a higher standards of transparency, accountability, and performance.

We are committed to creating higher quality jobs and improving the quality of life in our communities.

Opposite season operation

- Availability of reheat: close to 100%
- Condensation during cooling: 20%
- How/when does the central system switch over: 30%+



TAITEM SERVICES

An overview of some of our service offerings

DESIGN

- MEP+FP and Structural
- Nine PEs
- Licensed in 13 states

ENERGY + SUSTAINBILITY

- M & V
- Construction oversight
- On-site Energy Mgmt
- Energy Research
- Utility Consulting

PROGRAM COMPLIANCE

- Passive House
- NYSERDA
- Utilities
- LEED

QUALITY ASSURANCE

- QA Contractor for NYSERDA's MF Energy Performance Portfolio since 2007
- Training, tech tips, etc.

DHW Setpoints and Controls

CONSIDERATIONS

- Hybrid Heat Pump operation modes
- Return water temperatures/expected loads
- Supply water setpoints

Suggestions:

- Specify the desired mode on drawings
- Design for minimal recirculation load, minimum supply and return water temperatures.

Change Mode of Operation

Press the "MODE" button to select operating mode.

Modes of Operation

- Energy Saver
- High Demand
- Heat Pump
- Electric
- Vacation

Mode	Efficiency	Recovery
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Heat Pump	High	Very Slow
High Demand	Low.	Very Fast
Energy Saver	Very High.	Fast
Vacation	Very High	None

30:00

Main issue was actually on refill of the system

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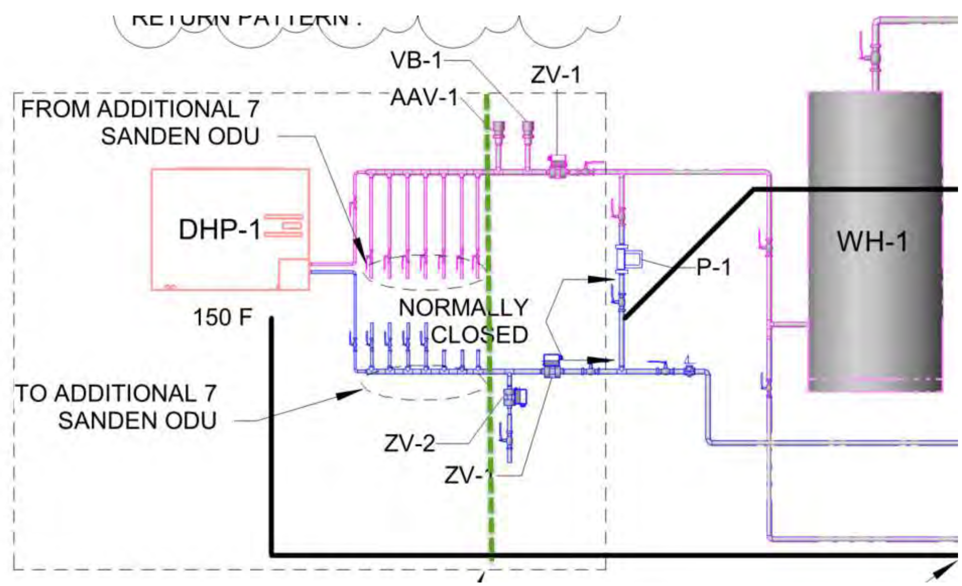
- More than could be handled by the automatic air vent
- Heat pumps were getting air bound and faulting out in error.

Solutions?

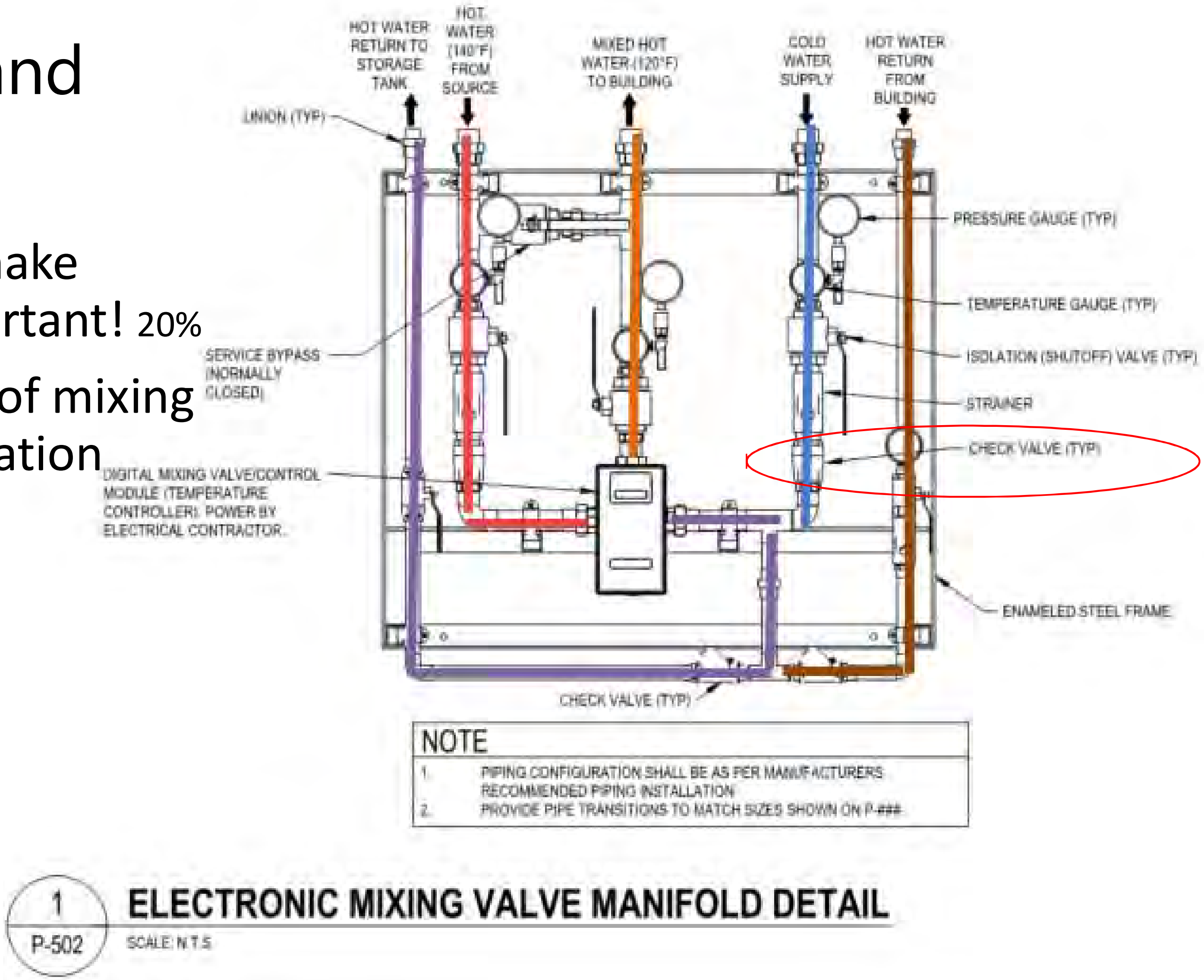


New Example

- Conference room we are currently in
  - Going to assume it is a RTU with VAVs, maybe with reheat coils
  - Designed for full occupancy conditions, peak load day
    - Also assuming we always have reheat hot water available
  - Designed as part of a system that most likely serves several other spaces with the same assumptions
    - Modulation and control down to actual occupancy IMPORTANT
  - Operation:
    - Central control system gets temperature and setpoint data from room thermostat
      - Enables/disables RTU, maybe even gives it a discharge air setpoint
      - Modulates VAV system, maybe even has CO_2 sensors in space to adjust ventilation assumptions
    - RTU packaged controls ramp up or down the system (under most conditions overshooting the setpoint, since it has to assume the space is under maximum load)
  - Human factor
    - Building staff receive complaints about overcooling/overheating → either pre-condition the space, or disable the system in response.
- SOLUTIONS
  - Design to accommodate normal use case (in addition to peak)
  - Careful controls sequence development – understand users, need for simplicity and on-demand+scheduling requirements
  - Ensure BMS/RTU and all systems in between communicating clearly – smooth modulation
    - CO_2 controls will save energy, but need to make sure they are not introducing lots of variability in operation
  - Good owner training, and cheat sheet style resources left in place

Mixing valves and recirculation

- Low flow fixtures make runout length important! 20%
- Careful integration of mixing valves with recirculation controls: 80%
- Recirculation pump setpoints: 60%



USING COMMISSIONING TO MAKE BUILDINGS BETTER

WHAT WE WISH EVERYONE KNEW

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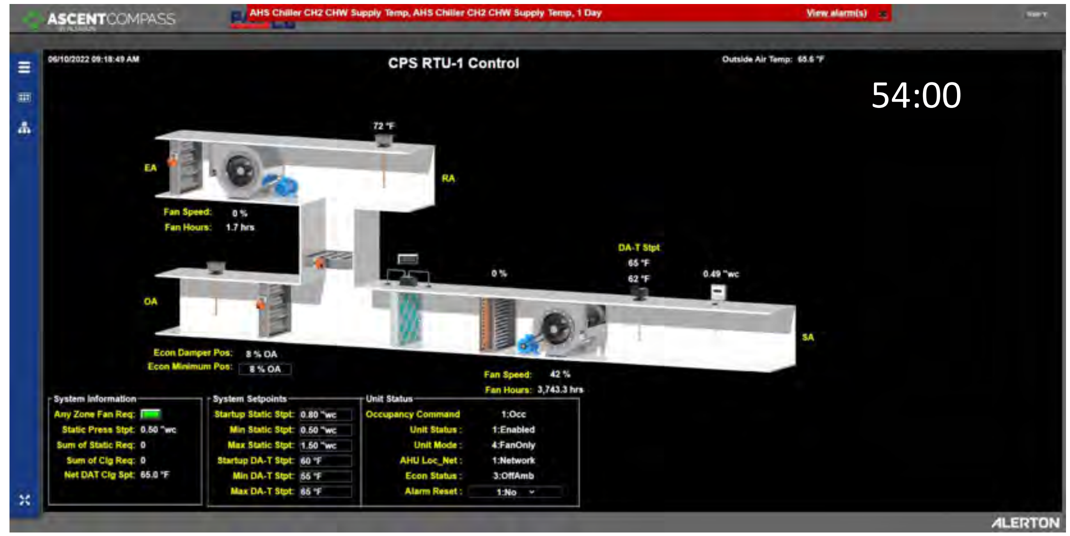
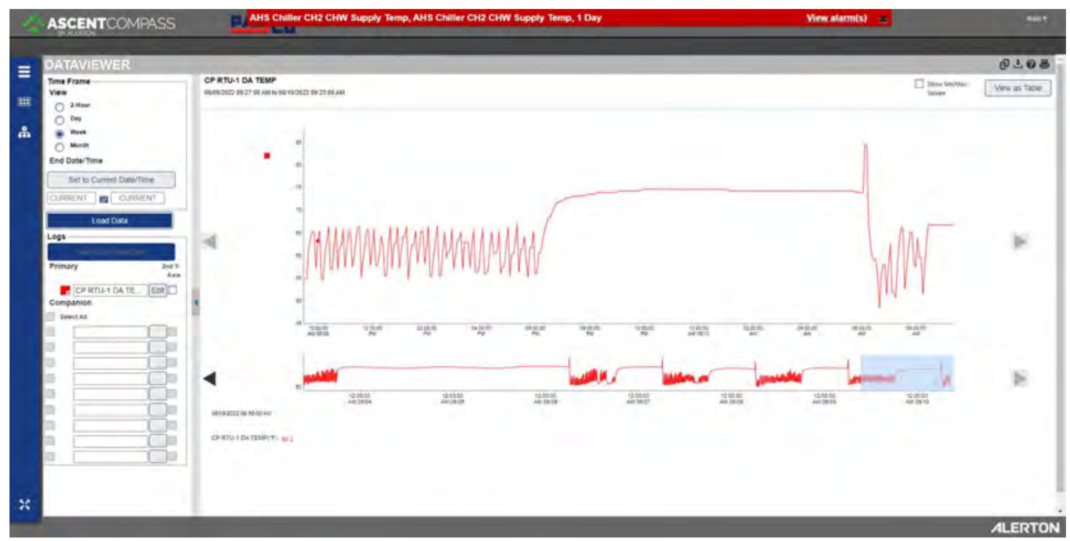
Certified B Corporation

Controls example

- Packaged controls integration with BMS –
  - RTU excessive SAT cycling
  - (+/- 5-10F, trends)

- Solutions?





36:00

Detour – Dual Temp Coils

- Freeze concern for multi-pass coils
  - Which side of the coil is the fluid entering
  - Was the coil sized for heating or cooling
  - What is the expected minimum flow and temperature range?

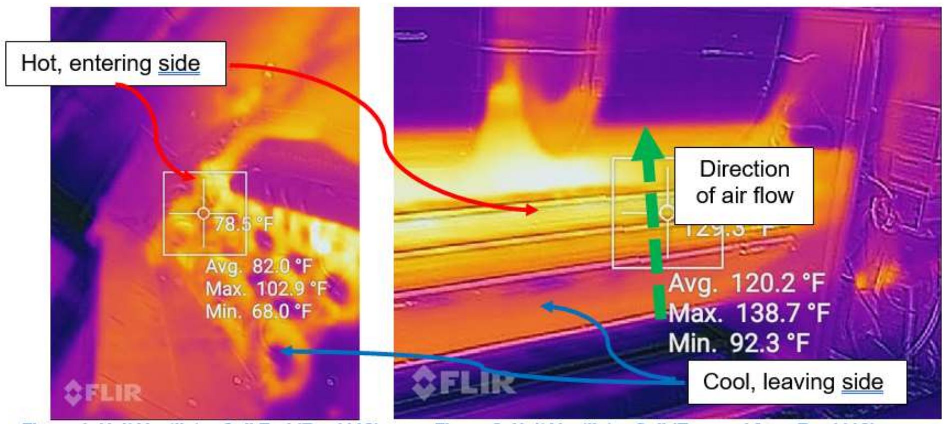


Figure 1- Unit Ventilator Coil End (Rm 111S)

Figure 2- Unit Ventilator Coil (Exposed face, Rm 111S)

46:00

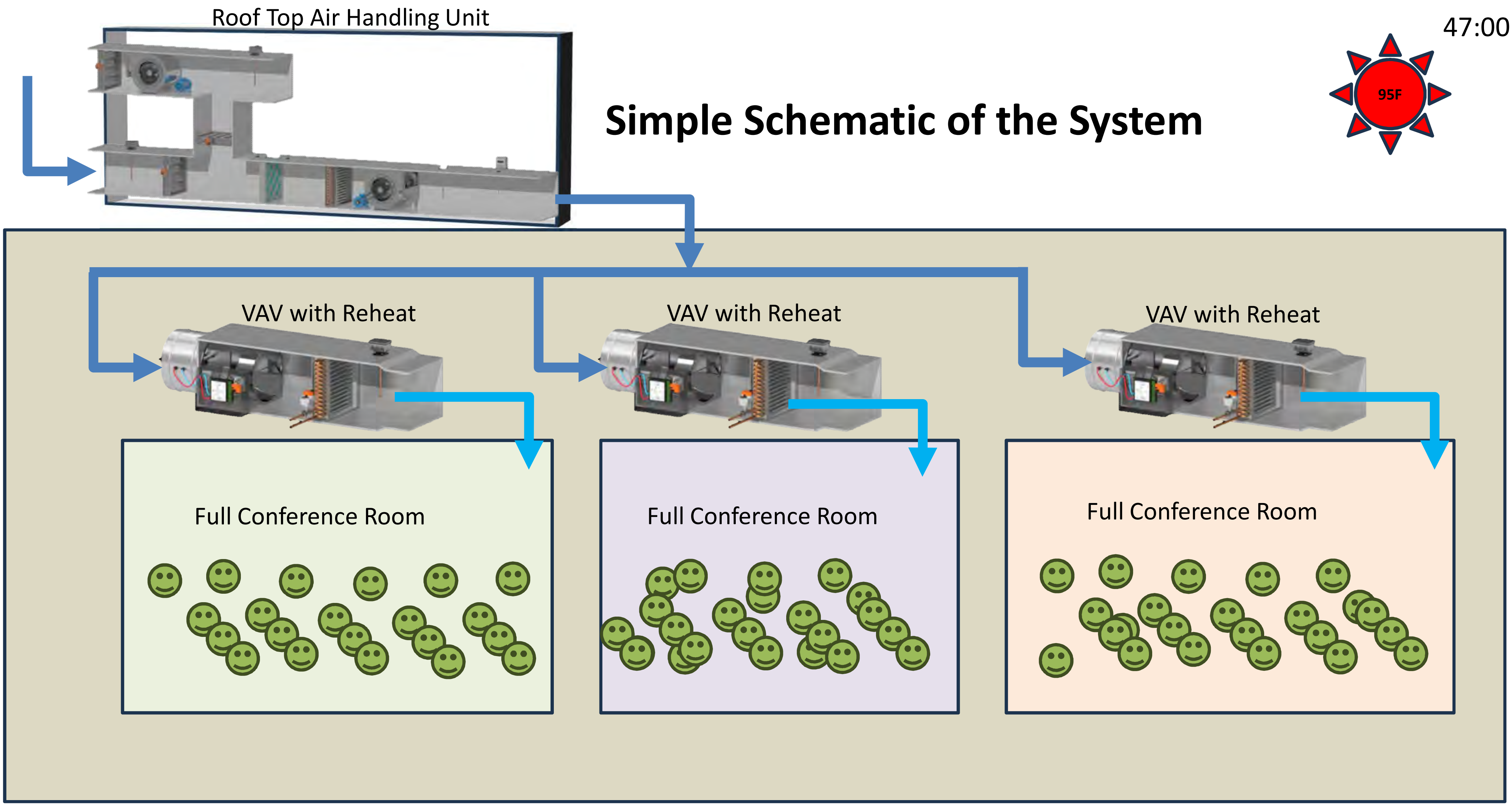
Controls

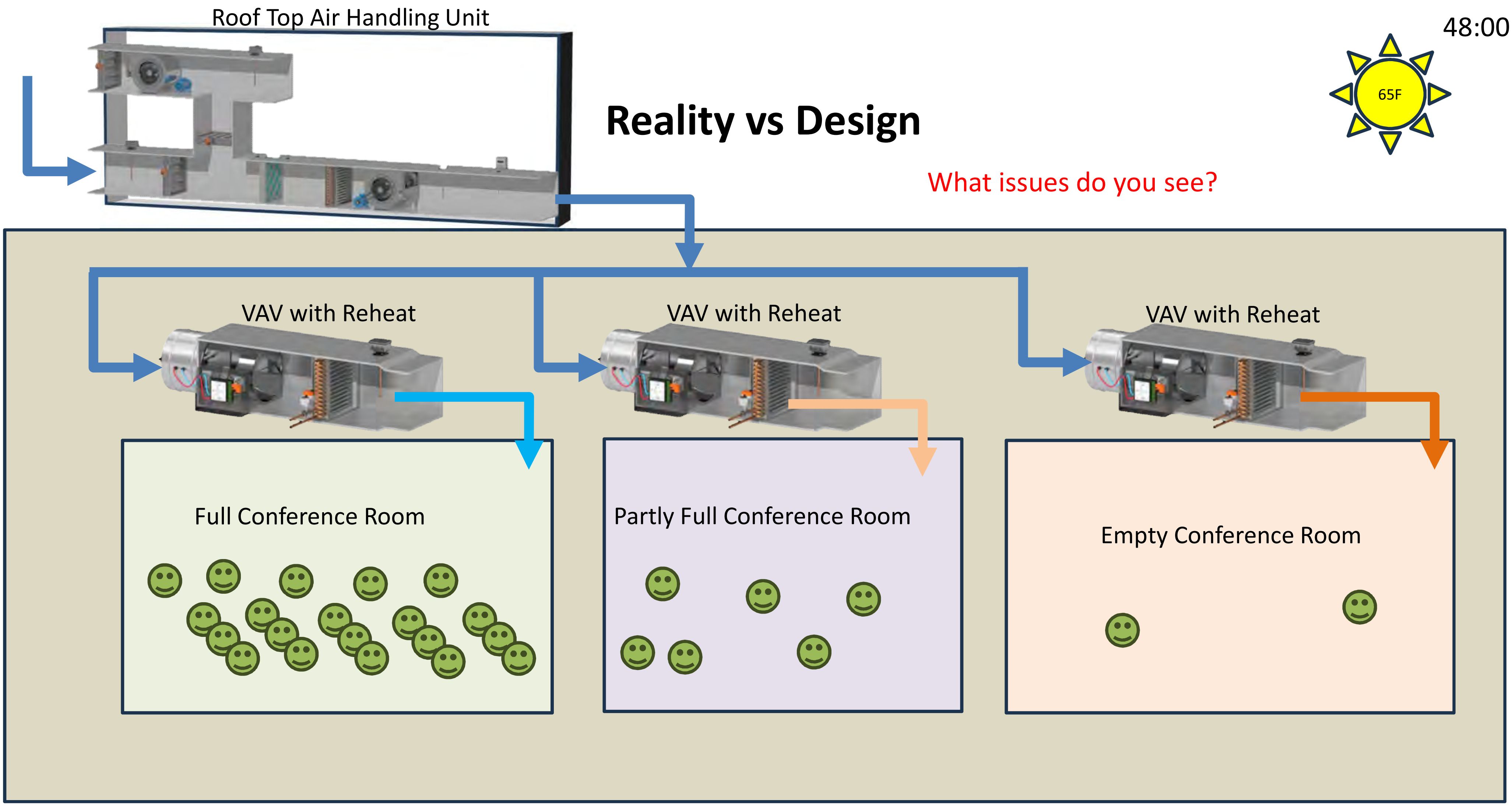
52:00

EXAMPLE

Controls

Simple Schematic of the System

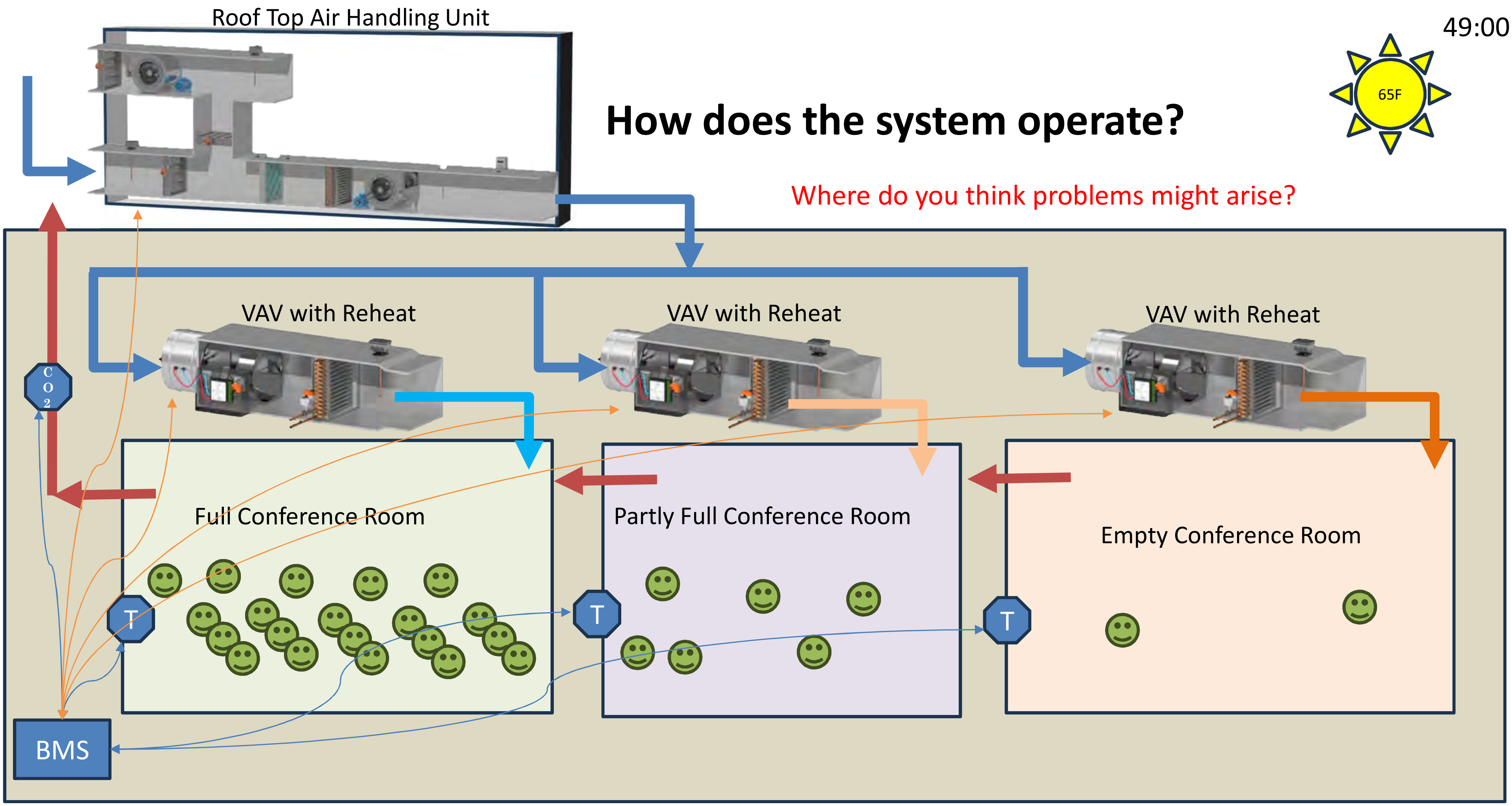



Roof Top Air Handling Unit
Reality vs Design
What issues do you see?
48:00
65F
VAV with Reheat
VAV with Reheat
VAV with Reheat
Full Conference Room
Partly Full Conference Room
Empty Conference Room

How does the system operate?

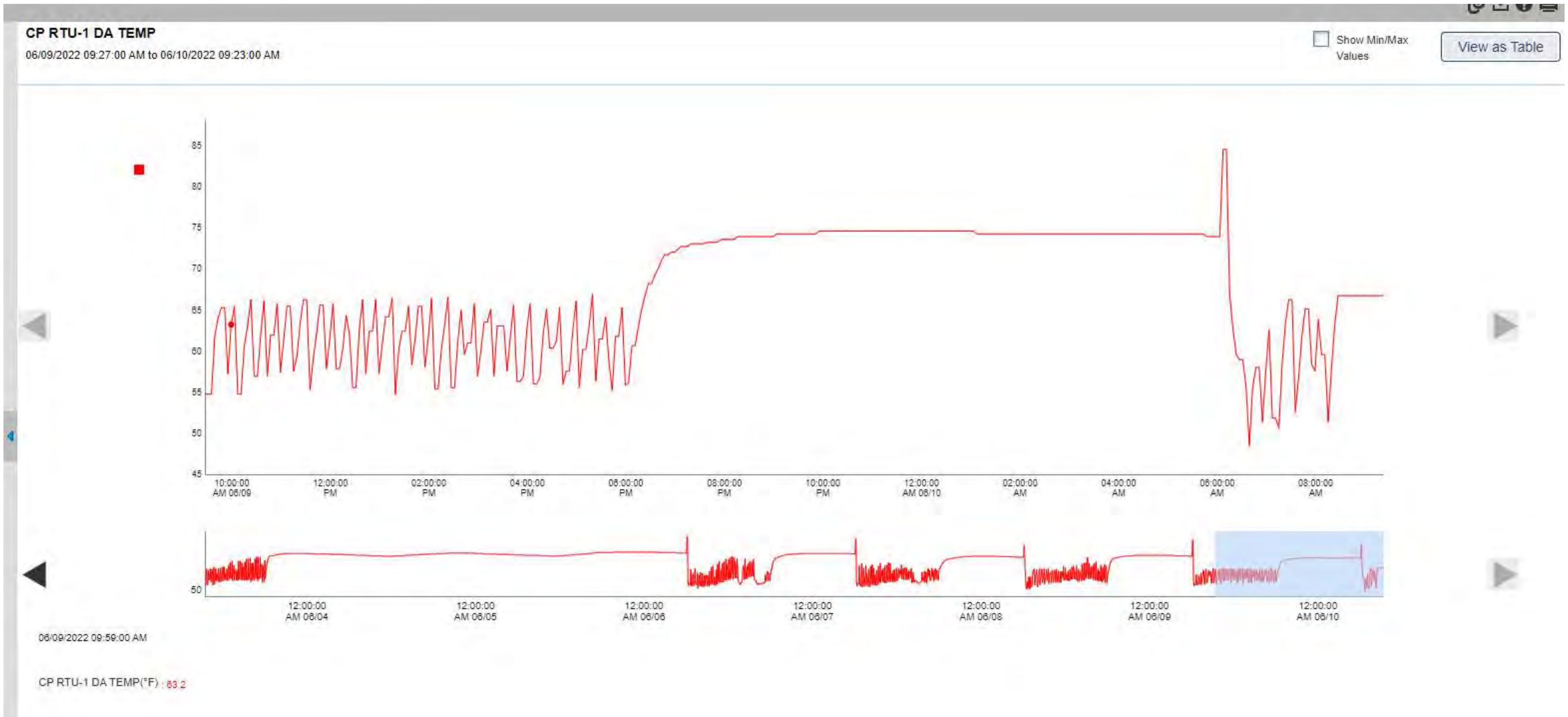
Where do you think problems might arise?

49:00



What actually happens?

Can anybody explain what is happening with this graph of the system discharge air temperature?



Recap: The Issues-

1) System sizing (oversized) - Design
2) Limited low end modulation – System Selection/Submitted Units/Min Ventilation Requirements
3) Summer reheat availability? – Building Operations/Design
4) Integration of Packaged and BMS controls – Controls Installation/Manufacturer Sequencing

Leading to: Comfort issues and manual overrides

Human Factors

- Space pre-cooled in anticipation of attendance (systems can’t respond instantly)
- Very responsive to occupant complaints
  - Units disabled, setpoints adjusted

- Doors open/closed, erratic space schedules

https://www.flickr.com/photos/chris_radcliff/172619346

51:00

Solutions?

- Design to accommodate normal use case (in addition to peak)
- Careful controls sequence development – understand users, need for simplicity and on-demand + scheduling requirements
- Ensure BMS/RTU and all systems in between communicating clearly – smooth modulation
  - Write this into the specs and ensure the system is fully tuned with post-occupancy trending and testing.
- Good owner training, and cheat sheet style resources left in place

What other solutions can you come up with?

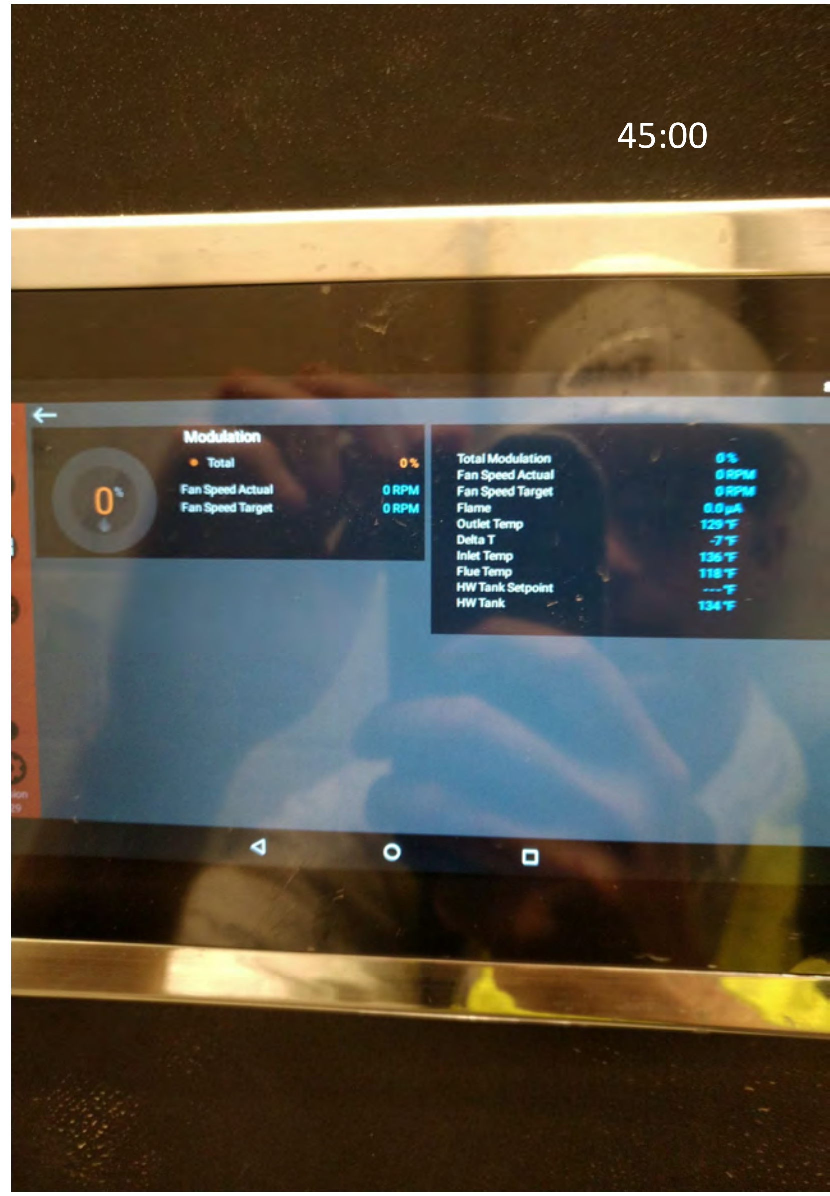
The Issue?

- Remember this is a VAV system serving a school office.
  - School is out over the summer, but the office stays open.
- Boiler plant is turned off for the summer

- Availability of reheat!
  - Spaces overcooled

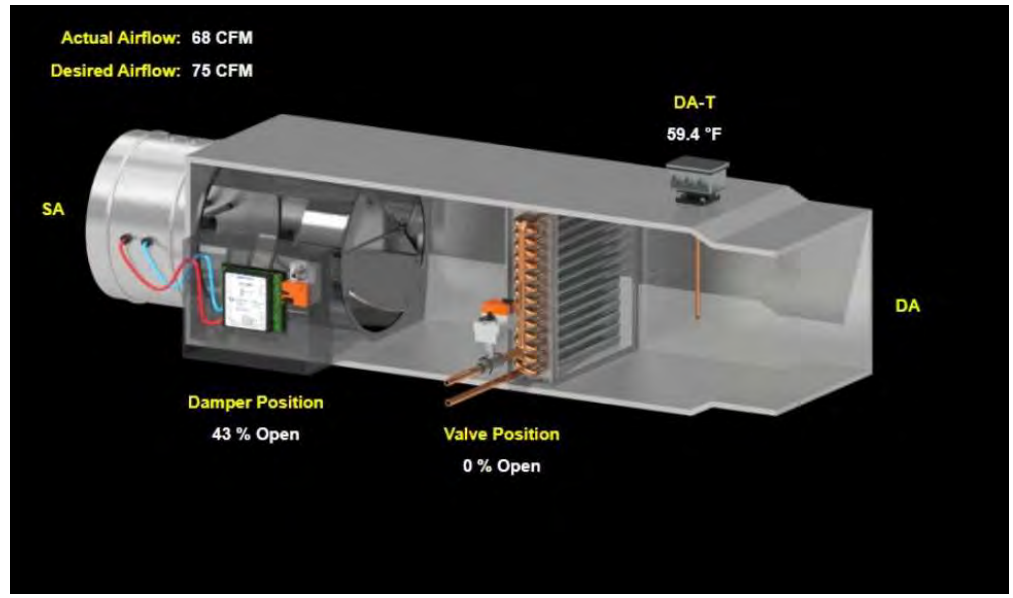
Solution:

  - Switchover sequence the operates differently when reheat is not available



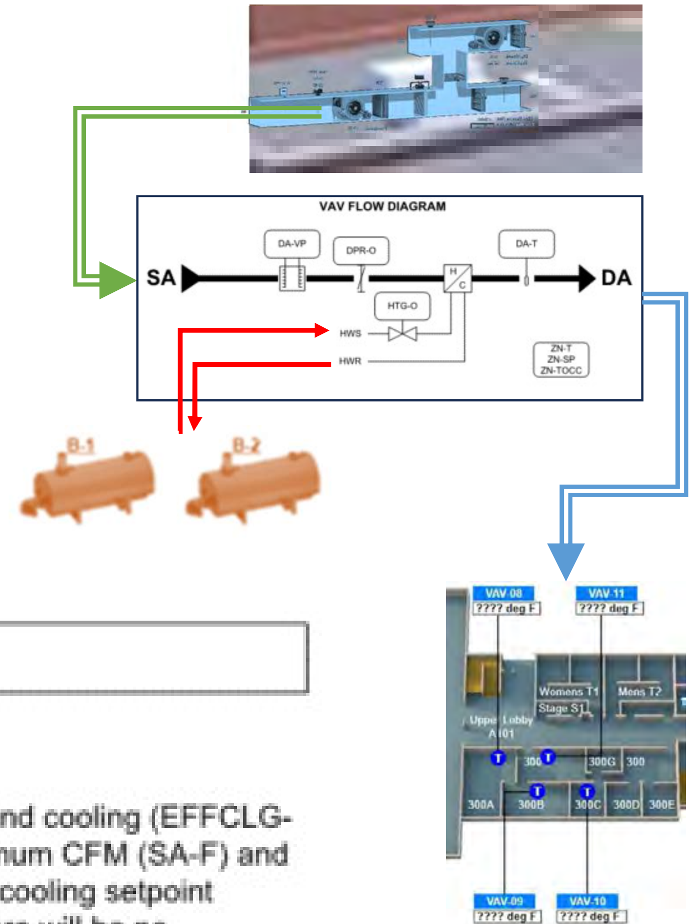
Typical VAV with Reheat sequence

- Central AHU provides air to all VAVs
- AHU supply air temperature controlled based on how cold it needs to be to satisfy the hottest space (and/or satisfy dehumidification needs).
- All other VAVs use reheat coils to heat that cold air so their spaces are comfortable.
- VAVs also modulate a motorized damper between minimum and maximum flows to deliver more or less conditioned air to space.



School Offices – served by VAVs

- Dedicated rooftop unit serves VAV system
- Central Heating Plant serves VAV reheat coils
- Offices stay open all summer

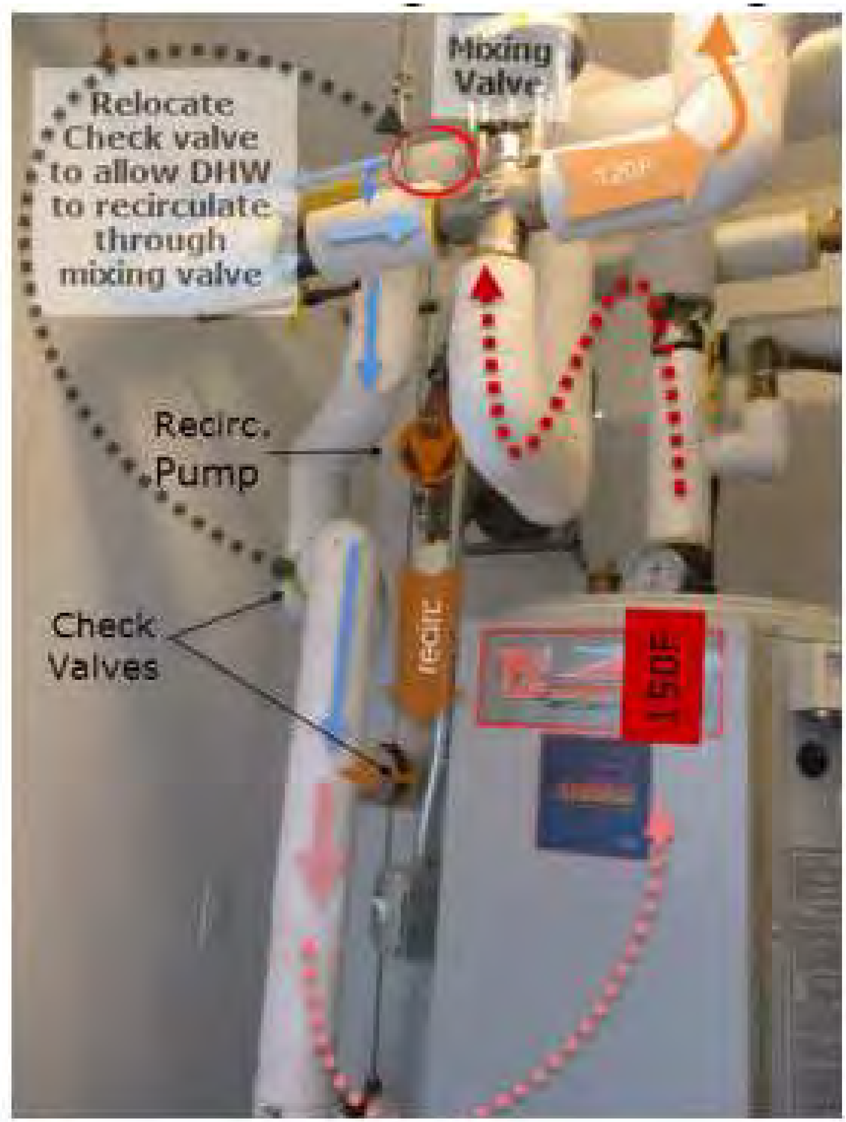


SEQUENCE OF OPERATION

OCCUPIED MODE:
When the zone temperature (ZN-T) is between the occupied heating (EFFHTG-SP) and cooling (EFFCLG-SP) setpoints (inside of the bias), the primary air damper (DPR-O) will be at the minimum CFM (SA-F) and there will be no mechanical heating. On a rise in zone temperature (ZN-T) above the cooling setpoint (EFFCLG-SP), the primary air damper (DPR-O) will increase the CFM (SA-F) and there will be no mechanical heating. On a drop in zone temperature (ZN-T) below the heating setpoint (EFFHTG-SP), the reheat coil will be fully utilized before the supplementary heat coil is enabled and the damper (DPR-O) is controlled to provide a minimum CFM (SA-F).

Expansion tanks and check valves

- Need to understand where these are in the system, and what effect they will have:
  - 20-30% of projects have some check valve/expansion related issue
  - Some equipment has internal check valves!



ADD: DHW Setpoints and Controls

- Condensing DHW setpoints (need condensing return temperatures)
- HP setpoints (storage temperature impacts resistance heat use – mixing down to 120F doesn't help you if you are generating it at higher temperatures)
- HP/Hybrid system efficiency settings ('comfort mode')

Change Mode of Operation

Press the "MODE" button to select operating mode.

Modes of Operation

- Energy Saver
- High Demand
- Heat Pump
- Electric
- Vacation

Mode	Efficiency	Recovery
Electric	Very Low	Fast
Heat Pump	High	Very Slow
High Demand	Low.	Very Fast
Energy Saver	Very High.	Fast
Vacation	Very High	None