

BUILDINGENERGY BOSTON

Fun with Monitoring: Using Data to Solve Problems From Design Through Occupancy

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Fun With Monitoring - Using Data to Solve Problems From Design Through Occupancy



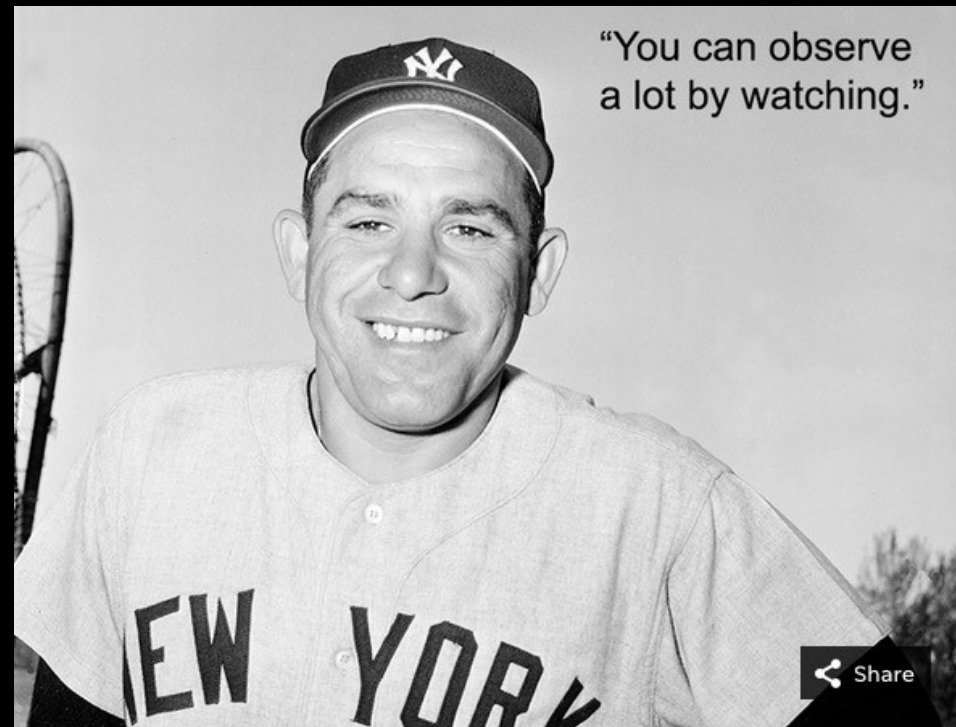
Building Energy Boston 2022

A Simple Caveat



Why Bother?

- Measure the performance of a building or system
- Solve a problem – identify cause(s)
- Identify a problem heretofore unnoticed
- Demonstrate the cause of a problem to a skeptic
- Determine proper inputs for design
- Understand cause and effect
- Learn something!



Types of Monitoring

- Long term, leave in place
- Short term, solve a problem
- Instantaneous, measure one data point

Onset Computer

Onset Computer Hobos

- Old style multi-channel with 2 external channels and internal T, RH
- Multi-channel with 4 external channels, LCD, more data storage
- 50A current transformer (CT)
- 50 ft indoor/outdoor temperature sensor


These older units require a laptop and a cable to launch and read out – newer ones are Bluetooth



Hoboware


Launch Logger

HOBO UX120-006M 4 Channel Analog

 Name:





Status... Serial Number: 10865560

Deployment Number: 19

Battery Level:  100 %

Sensors

Configure Sensors to Log:

<input checked="" type="checkbox"/>	1)	TMCx-HD (-40F to +212F)	Outdoor temp	LCD units: F	
<input checked="" type="checkbox"/>	2)	CTx-A (0-20 Amp AC)	Boiler burner	LCD units: AMP	
<input checked="" type="checkbox"/>	3)	CTx-A (0-20 Amp AC)	<Enter label here>	LCD units: AMP	
<input checked="" type="checkbox"/>	4)	CTx-B (0-50 Amp AC)	<Enter label here>	LCD units: AMP	
<input type="checkbox"/>	5)	Logger's Battery Voltage			

Deployment

Logging Interval:

Logging Mode:

Logging Duration: 179.2 days

Start Logging:

Stop Logging: When memory fills Never (wrap when full)

Push Button

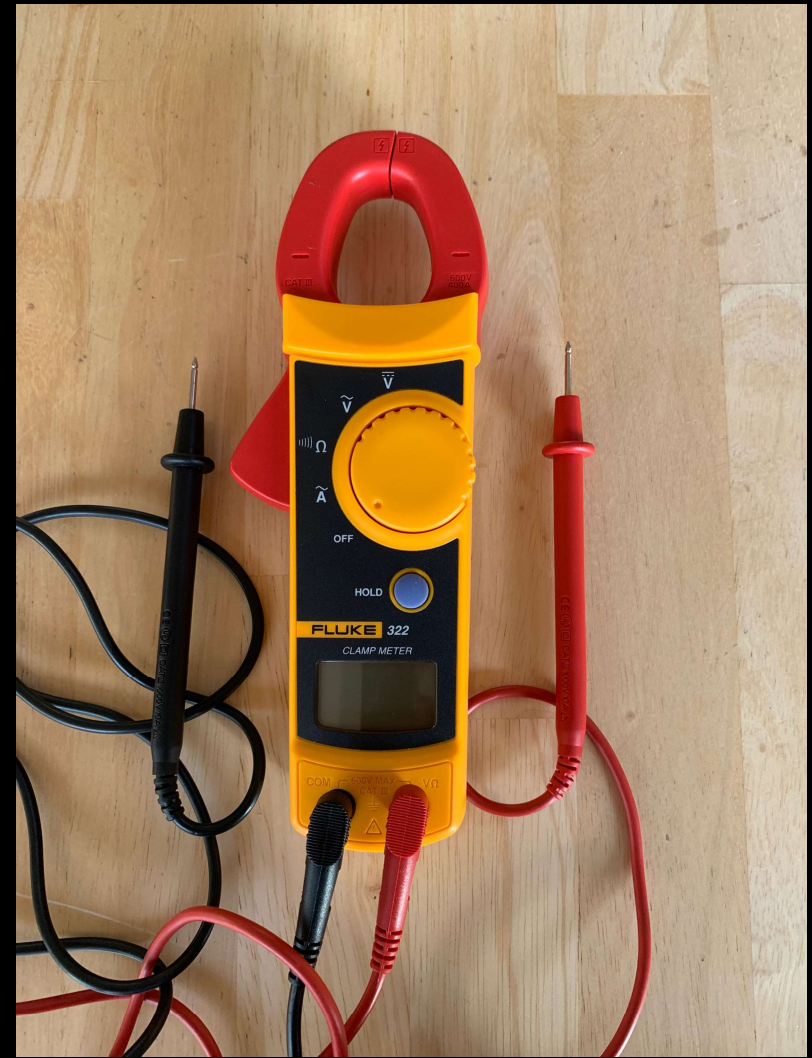
After

Options: Turn LCD off

Skip launch window next time

Digital Multi-meter

- Instantaneous measurement, although logging ones are available
- Amps, AC voltage, DC voltage, Ohms



Digital Thermocouple

- This one has two channels
- Thermocouple is slender, reacts quickly



Kill-A-Watt

- For 120 VAC loads
- Plug into receptacle, plug device into it
- Available in logging version to aggregate kWh usage as well as wattage drawn



CO2 Sensor

- Use with a Hobo logger
- Onset has dedicated sensor/loggers
- Self-calibrating – I put it outdoors periodically to check



Radon

- Hourly readings
- Download via Bluetooth to phone



Omnisense

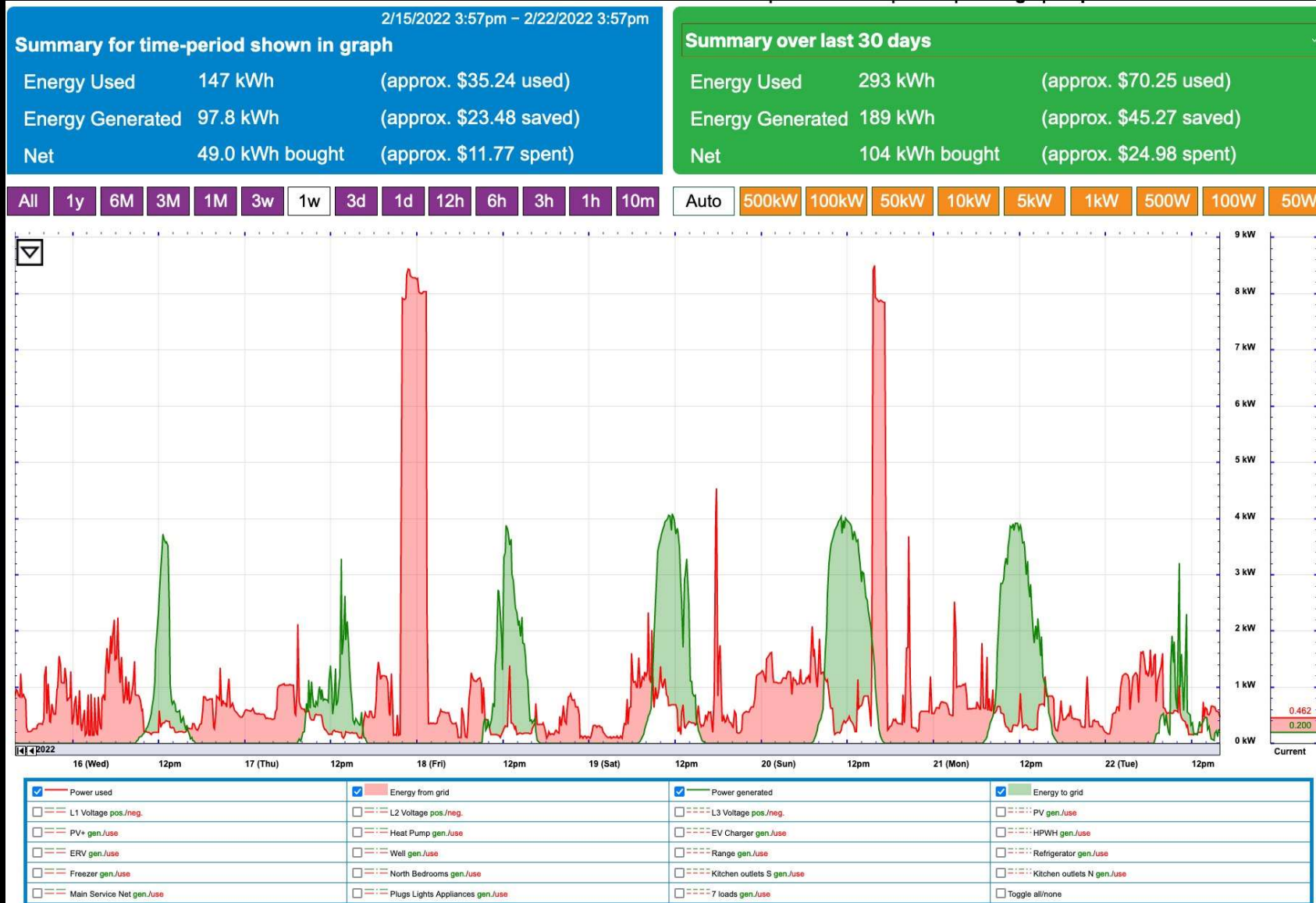
- Web-accessible monitoring
- Temperature, RH, dewpoint, CO2, moisture content,.....

The screenshot displays the Omnisense website's product page for Wireless Sensors. The header features the Omnisense logo, a search bar, and navigation links for Wireless Gateways, Wireless Sensors, DriFi™ Monitoring, Accessories, Monitoring Service, and Distributors. The main content area is titled 'Wireless Sensors' and includes a 'Sort by' dropdown set to 'Position' and a 'Display' dropdown set to '25 per page'. Below this, three product listings are visible:

- S-1 Wireless T, %RH, WME Sensor (The S-1 is obsolete and has been replaced by the S-11.)**
☆☆☆☆☆
From \$50.41
- S-11 Wireless T, %RH, WME Sensor**
☆☆☆☆☆
From \$50.41
- S-2 Wireless Sensor with 2 ports for T and %RH, WME socket and 64K Reading Datalogging Memory, ±0.3°C/±2.0%RH**
☆☆☆☆☆
From \$59.95

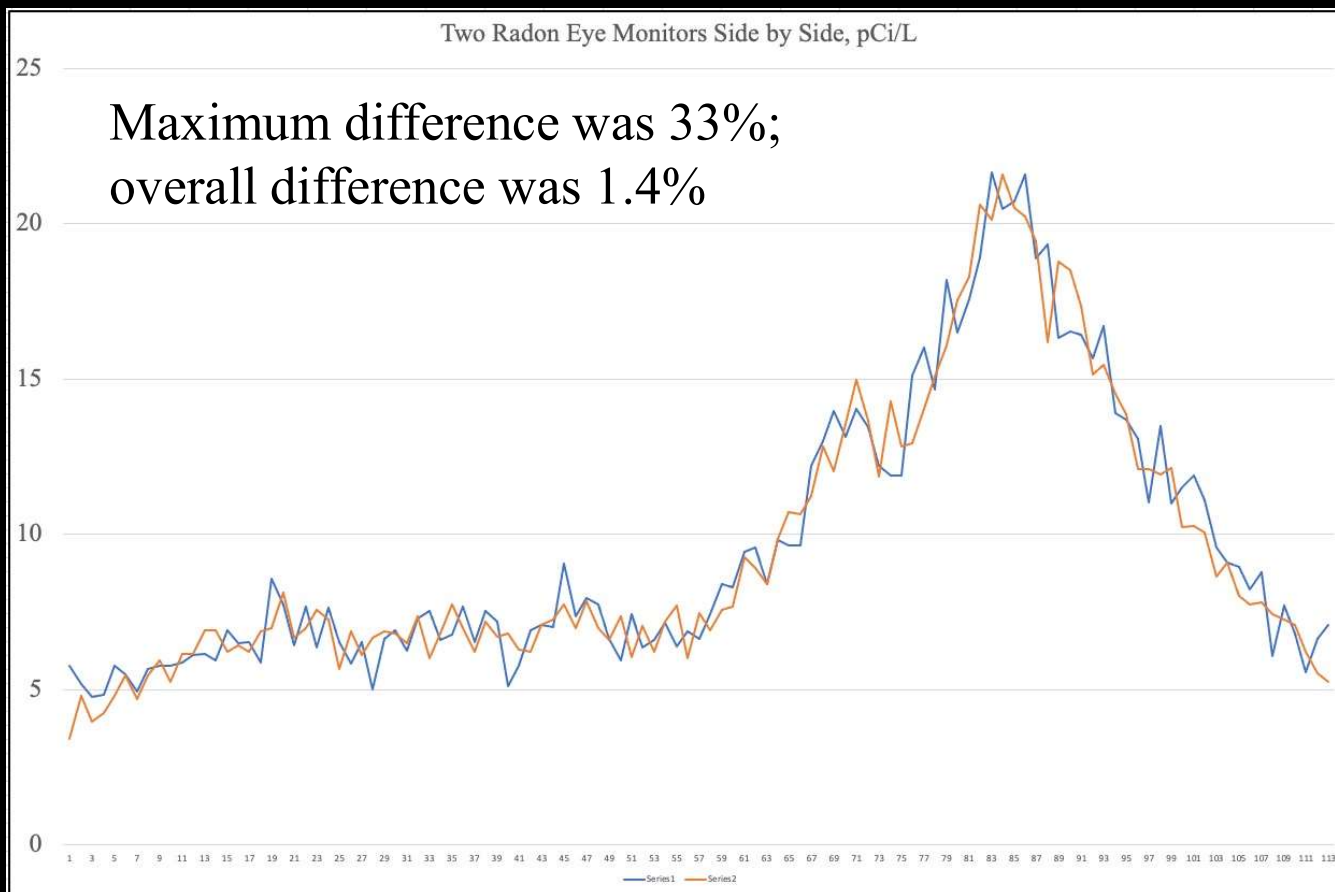
Each listing includes an 'ADD TO CART' button and icons for wishlist and share. The left sidebar contains a 'Categories' menu with 'Wireless Sensors' selected, a 'Popular tags' section with tags like 'datalogging', 'gateway', 'Humidity', 'Moisture Meter', and 'Temperature', and a list of product types including 'omnisense cellular gateway wifi 3G gsm' and 'omnisense cellular gateway wifi nb-iot lte cat-m1'.

Circuit by Circuit Monitors



Calibration

- Can the instrument be calibrated to a known standard?
- Can sensors of the same type be calibrated to each other?
- Is each measurement critical or can the results be averaged?

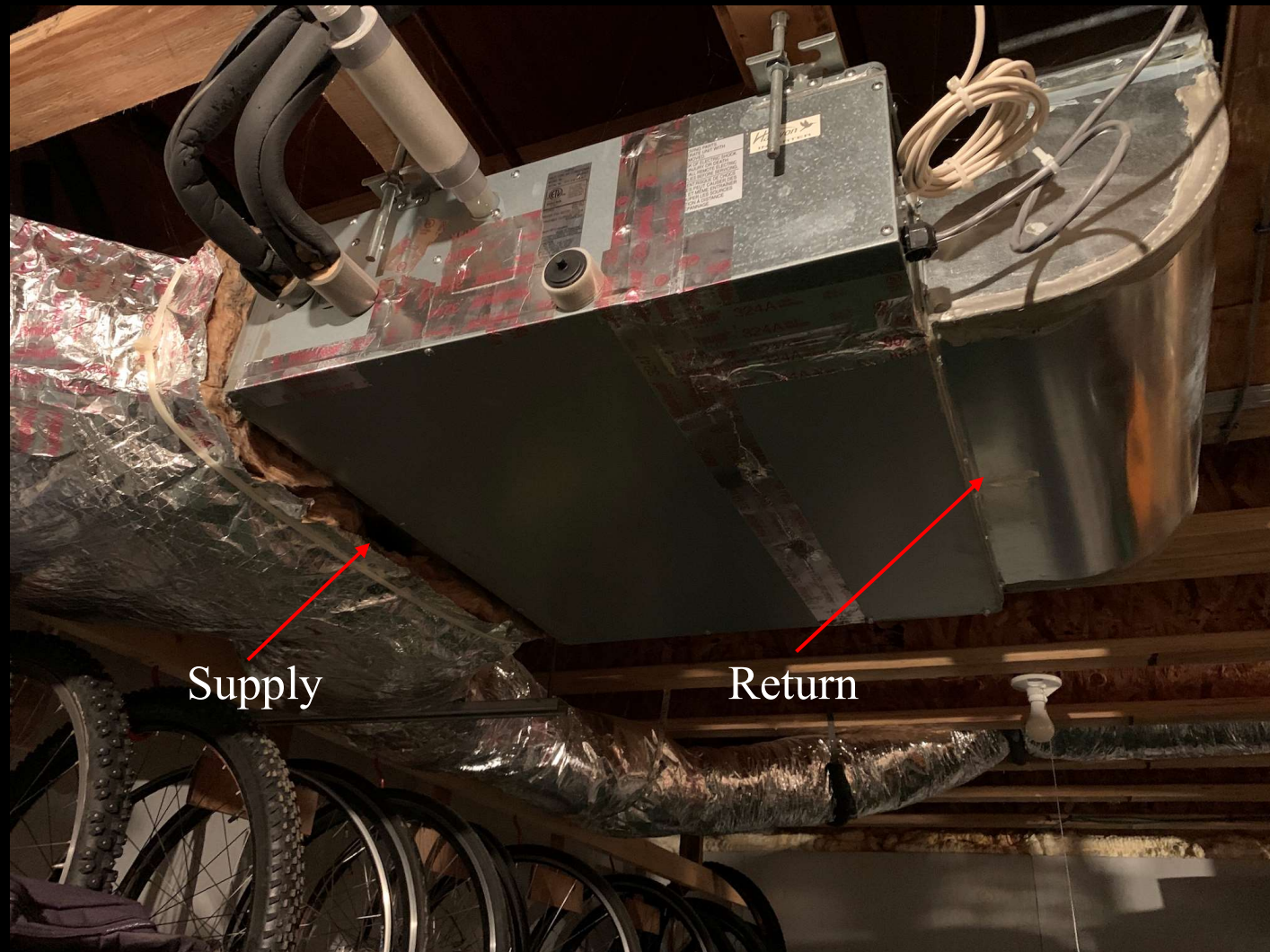


Accuracy vs. Precision

- Accuracy of a set of measurements is how close they are to the true value
- Precision of a set of measurements is how close they are to each other (repeatable)
- *How accurate do the measurements need to be to be useful?*

Accuracy – Use One Sensor?

- Example – measure the temperature rise across a ducted heat pump.



Case #1

Measure the performance of a building or a system

Heat Pump COP @ -7°F

- Temperature rise across the air handler = 39.8 °F
- Flow rate 368 CFM (Duct Blaster measurement)
- Input power 2.09 kW
- $39.8 \times 368 \times 1.08 / 3,412 \text{ BTU/kWh} = 4.64 \text{ kW}$
- $\text{COP} = 4.64 / 2.09 = 2.22$

- How much energy goes to the basement via conduction?
- ΔT across the supply registers and the return grille was 35.4 °F
- $(39.8 - 35.4) / 39.8 = 11\%$

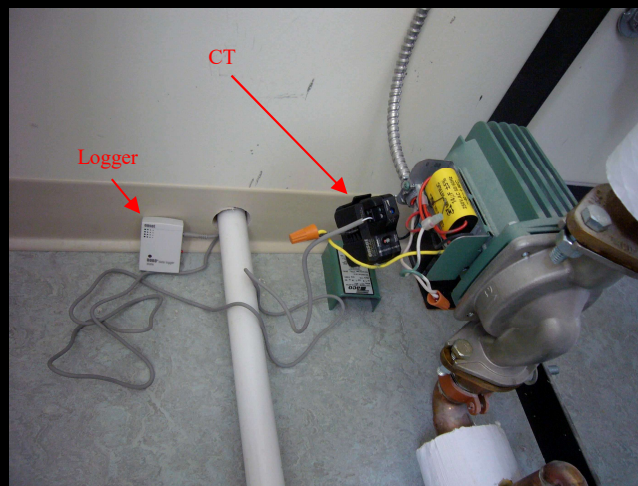


Case #2

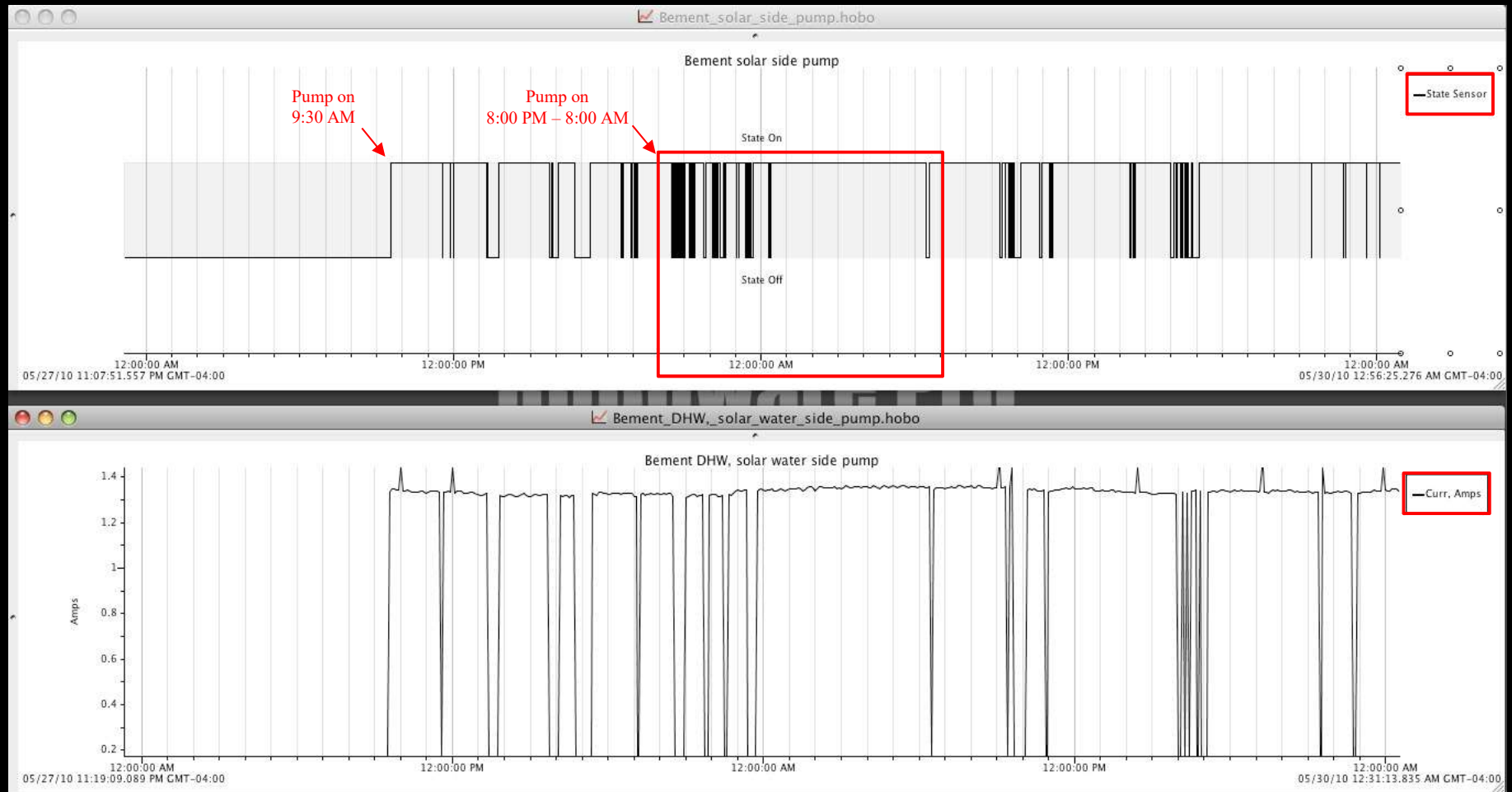
Identify and solve a problem

The Case of the High Hot Water Energy

- 10,000 sf dorm – 4 faculty apartments, 10 double dorm rooms – 28 occupants
- 240 sf drainback SDHW system – two 120 gallon solar storage tanks with 120 gallon electric back-up
- Monitoring showed that back-up electric energy was higher than expected, while DHW usage was in line with modeled usage
- Installed Hobo dataloggers with current transformers on the solar array pump and on the potable side pump, as well as on the heating elements in the back-up tank



The Case of the High Hot Water Energy



The pumps were running at night – controller was faulty.
These are *solar* hot water systems, not *lunar* hot water systems

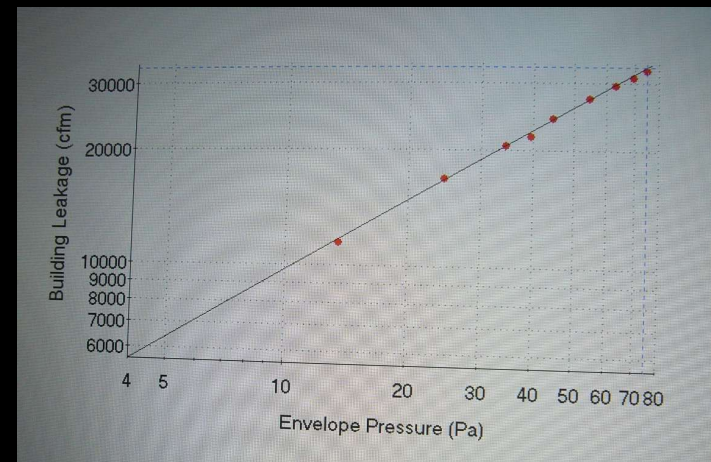
Case #3

Identify and solve a problem

The Case of the High Average Energy Use



- 226,500 sf university building
- Excellent peak load performance (1,100 sf/ton)
- Annual energy performance less stellar



The Case of the High Average Energy Use

- Peak electrical use was 1.75 W/sf
 - Lighting 0.55 W/sf
 - Plug loads 0.28 W/sf
 - Other 0.92 W/sf (NB: 178,400 sf underground parking garage, commercial kitchen)
- Average electrical load was 1.15 W/sf – 66% of peak – seemed high
- I asked MIT to look for something that was running all the time
- Kitchen hood was 6,000 CFM but variable speed based on cooking intensity
- Speed control uses an electric eye across the hood to sense opacity of exhaust (smoke), ramping up the exhaust fans as opacity increases
- Investigation showed that the hood was running at full speed 24/7
- Further investigation showed that fire suppression system piping *blocked* the electric eye, sending the false signal that exhaust opacity was always maximum
- MIT Director of Engineering estimated energy use impact as an additional **30%** annually

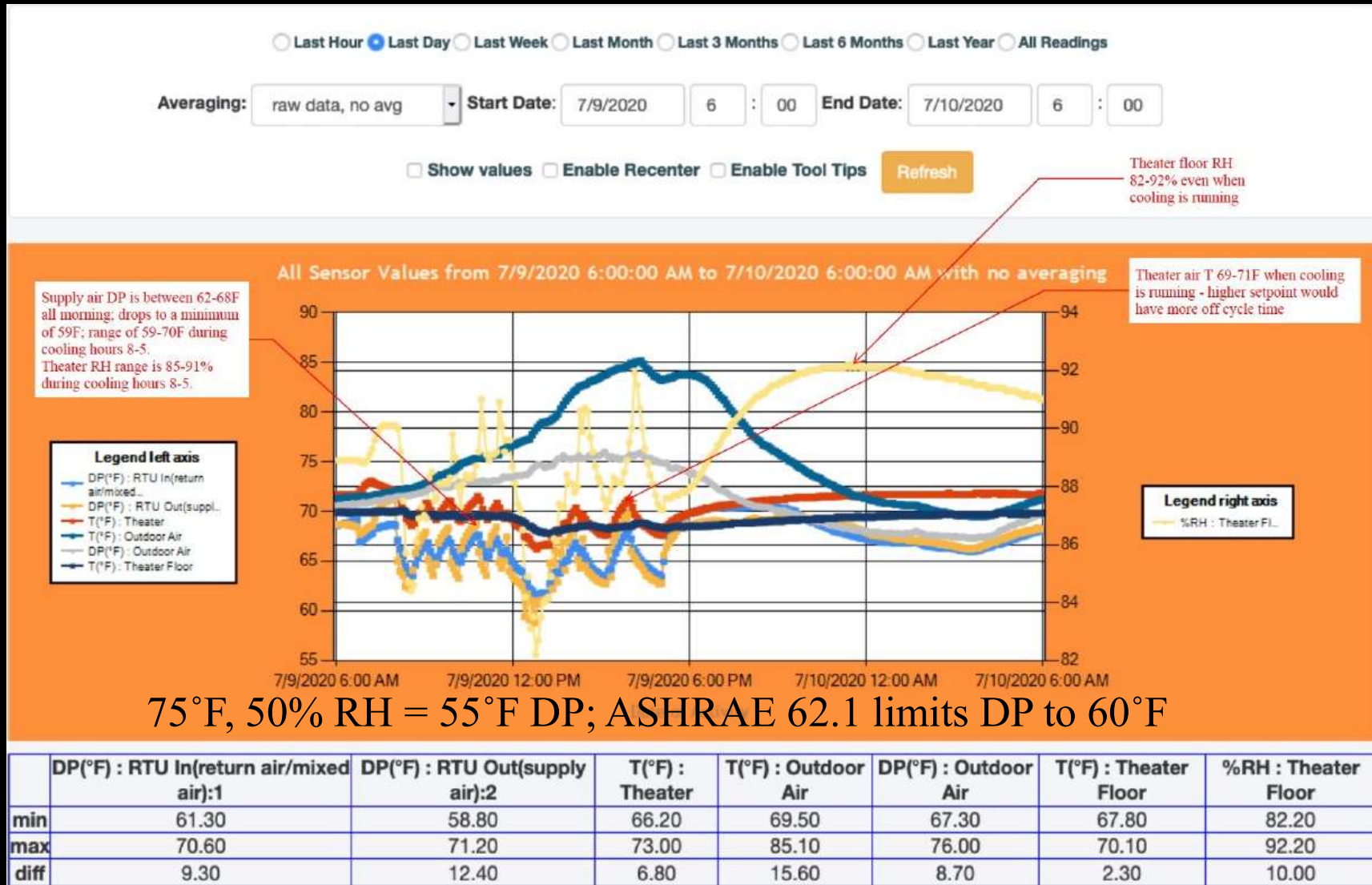
Case #4

Demonstrate the cause of a problem to a skeptic

The Case of the Moldy Theater

- 270 seat black box theater in coastal MA – 3 year old building
- Mold on seats and stage curtain
- RH over 80% in cooling season
- 10,000 CFM constant volume air handler with 4 stages of compressor modulation available
- Outdoor air was set to a maximum of 2,850 CFM and a minimum of 540 CFM with no energy recovery.
- To avoid over-cooling, the compressors are controlled by space temperature, so as the cooling load decreases, coil temperature and the discharge air temperature of the air rises. Dehumidification capacity falls off rapidly.
- Peak dehumidification load from occupants and ventilation air was 10-13 tons.
- Equipment dehumidification capacity was 3.8 tons.
- An Omnisense datalogging system was installed with the following points:
 - Theater air near floor
 - Theater air high
 - Outdoor air
 - Mixed air (return air/outdoor air) into the air handler coil
 - Discharge air from the air handler

The Case of the Moldy Theater



The Case of the Moldy Theater

Last Hour
 Last Day
 Last Week
 Last Month
 Last 3 Months
 Last 6 Months
 Last Year
 All Readings

Averaging:
 Start Date: :
 End Date: :

Show values
 Enable Recenter
 Enable Tool Tips

All Sensor Values from 7/9/2020 8:00:00 AM to 7/9/2020 12:00:00 PM with no averaging

Compressor off, supply dewpoint rises above mixed return air dewpoint - coil is humidifying the space as moisture evaporates.

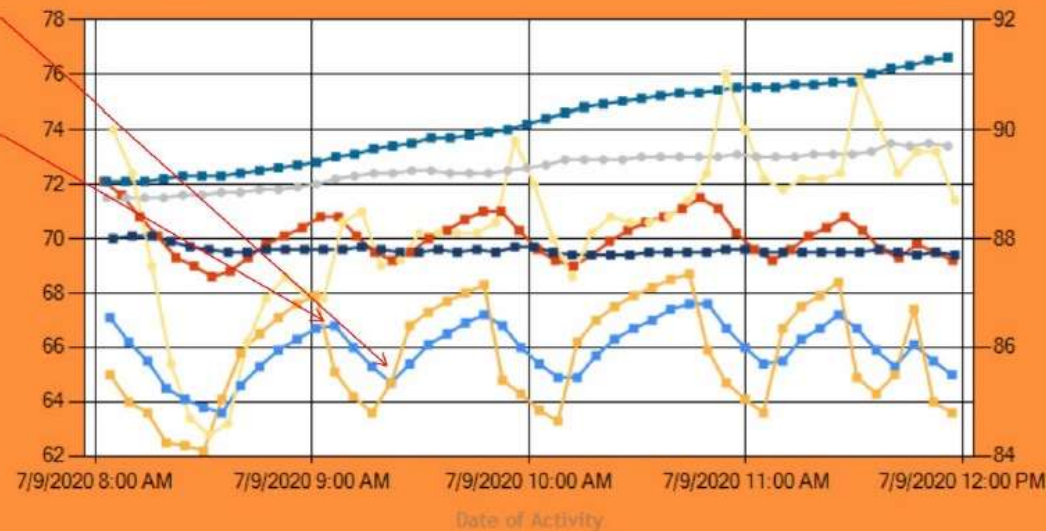
Compressor on, supply dewpoint drops below mixed return air dewpoint.

Legend left axis

- DP(°F) : RTU In(return air/mixed air):1
- DP(°F) : RTU Out(supply air):2
- T(°F) : Theater
- T(°F) : Outdoor Air
- DP(°F) : Outdoor Air
- T(°F) : Theater Floor

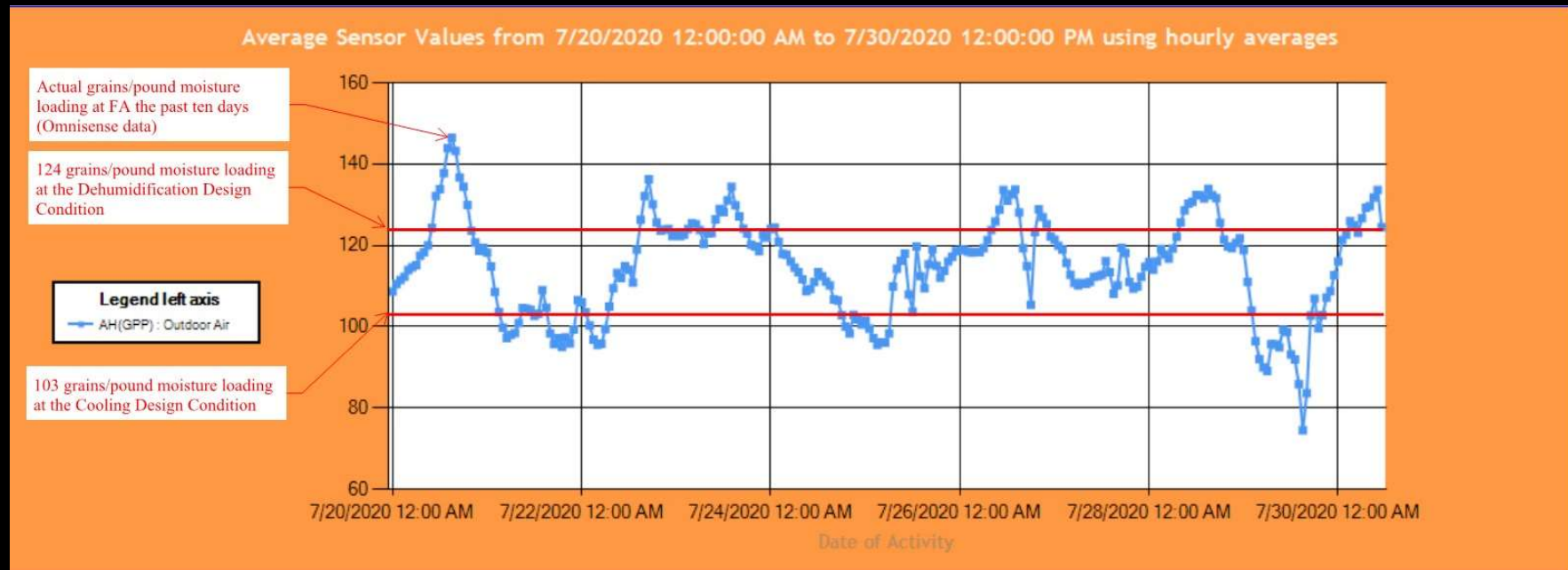
Legend right axis

- %RH : Theater Floor



	DP(°F) : RTU In(return air/mixed air):1	DP(°F) : RTU Out(supply air):2	T(°F) : Theater	T(°F) : Outdoor Air	DP(°F) : Outdoor Air	T(°F) : Theater Floor	%RH : Theater Floor
min	63.60	62.20	68.60	72.10	71.50	69.40	84.40
max	67.60	68.70	72.10	76.60	73.50	70.10	91.00
diff	4.00	6.50	3.50	4.50	2.00	0.70	6.60

The Case of the Moldy Theater



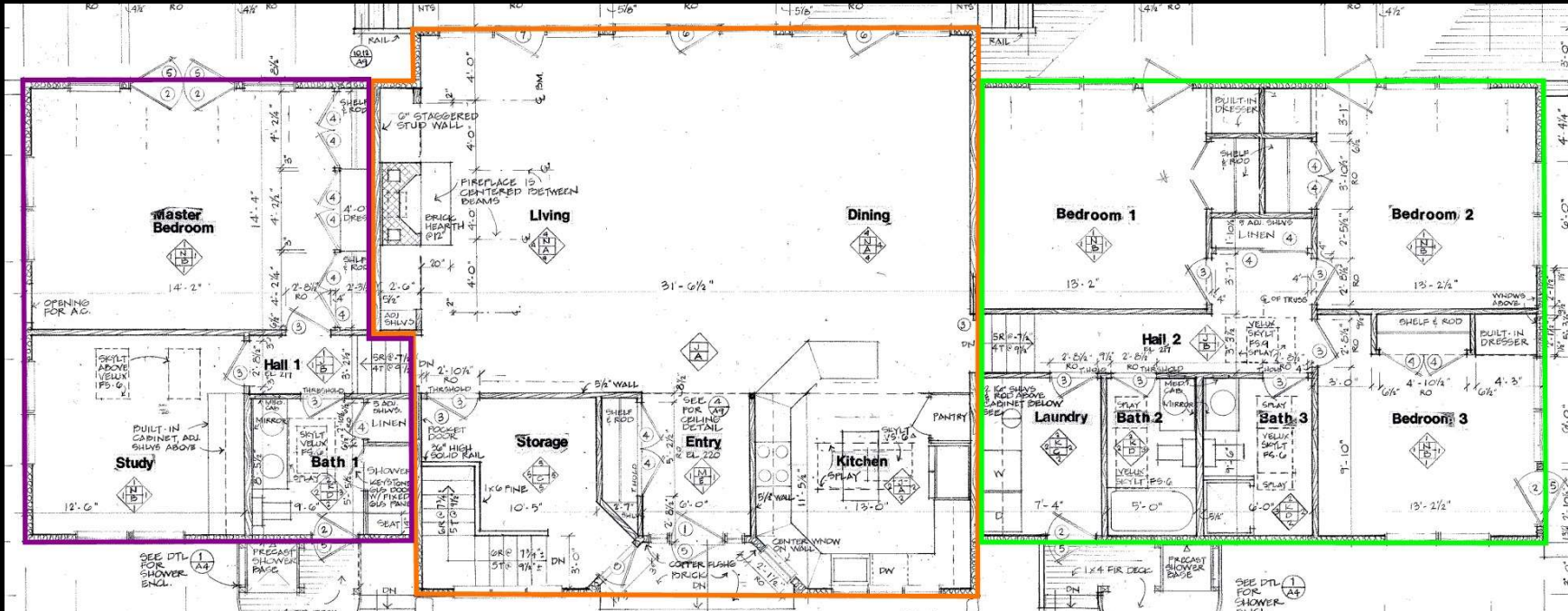
Design for Dehumidification moisture load of outdoor air is 20% higher than the Cooling Design moisture load. Peak moisture load observed was 19% higher than Design for Dehumidification load, and 44% higher than Cooling Design load.

Case #5

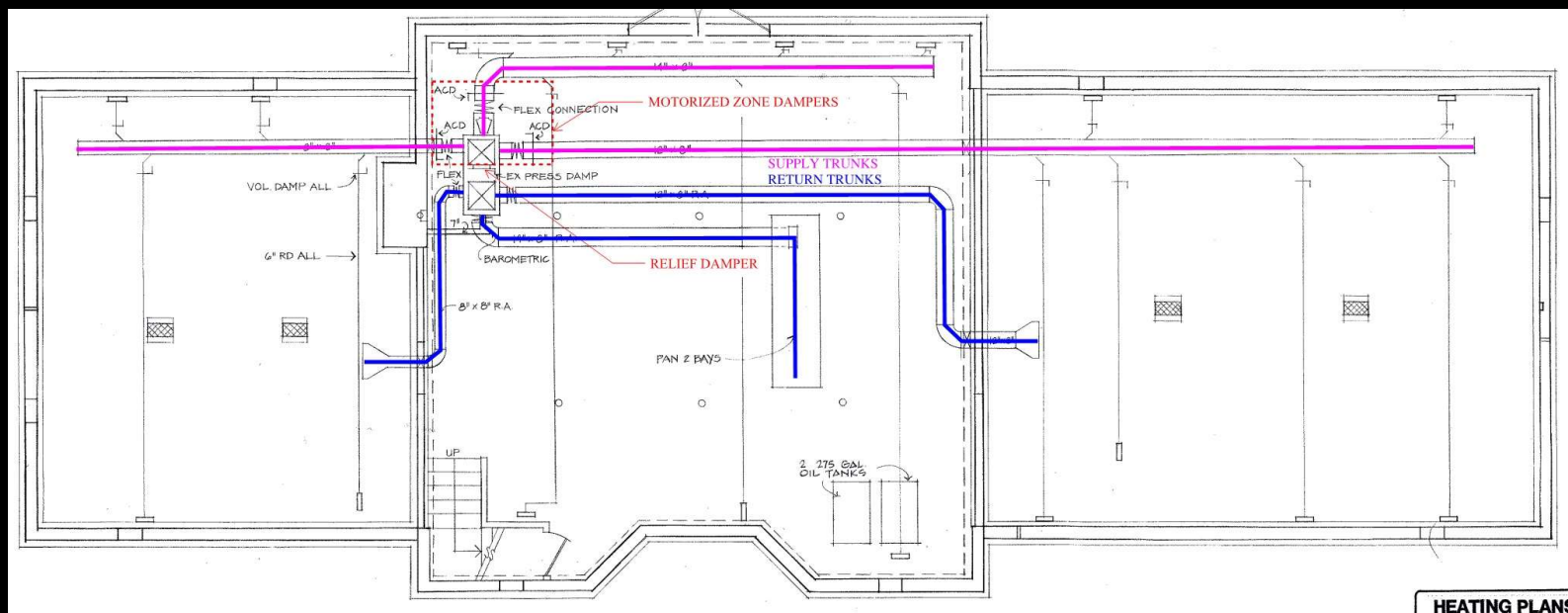
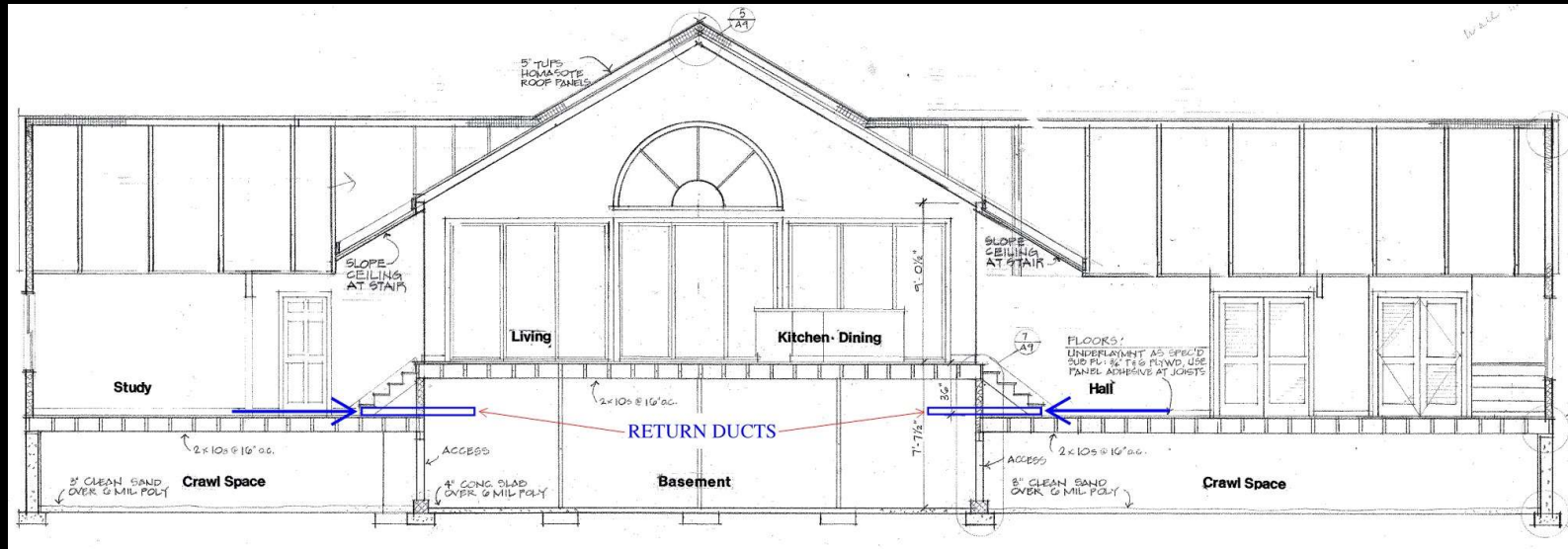
Demonstrate the cause of a problem to a skeptic

The Case of the Hot Basement

- 2,400 sf House, oil furnace, three zones with motorized zone dampers



The Case of the Hot Basement



HEATING PLANS

The Case of the Hot Basement



These are the **ONLY** returns in the house – the returns in the bedroom wing stair risers shown on the plan **ARE NOT THERE**

The Case of the Hot Basement



MOTORIZED ZONE
DAMPER (1 OF 3)

RELIEF DAMPER

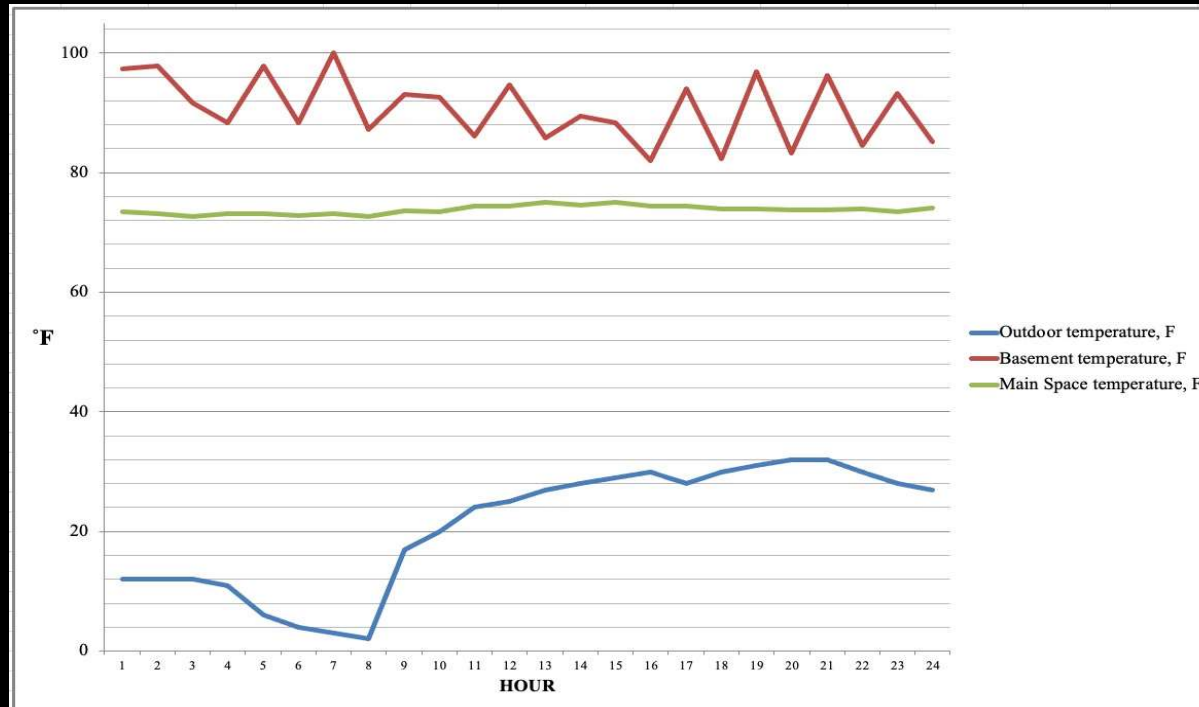
The gravity relief damper opens when zone dampers are closed, because the furnace has a constant flow fan and the air must go somewhere

The Case of the Hot Basement



Individual T/RH loggers in the main living space zone and outdoors, and a multi-channel logger with temperature sensors in each crawl space and the basement, as well as a current transformer on the oil burner to track burner run time

The Case of the Hot Basement



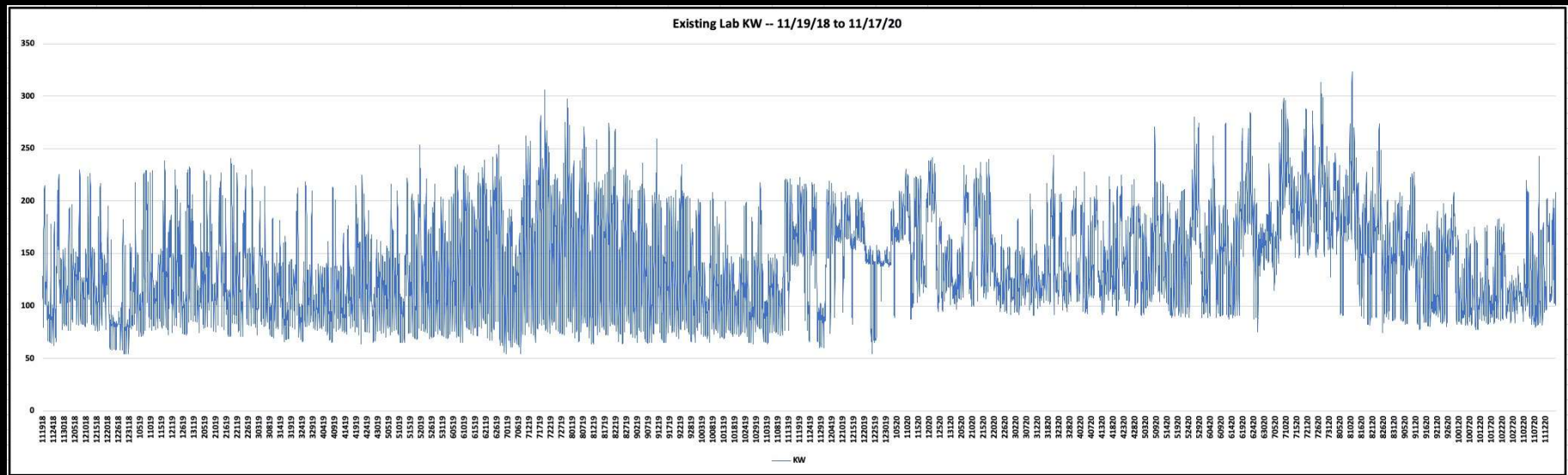
- One 24 hour period - outdoor temp drops to 2°F
- Bedroom wing zone thermostats are *never satisfied* due to inadequate CFM, so those zone dampers are open continuously
- Basement reaches 100°F because most of the supply air comes out the relief damper – main living space damper is always closed
- Main living space is always warm enough – heated by the unintentional radiant floor ☺ - slight warming due to solar gain 10 AM – 4 PM

Case #6

Determine proper inputs for design

The Case of the (Imaginary) Internal Gains

- Existing 22,000 sf lab building with planned 30,000 sf addition
- HVAC engineer's calculated cooling load for the addition was **323 tons** – which works out to $38W/sf$, much of which was modeled as lab internal gains
- 2 years' worth of 15 minute electricity data for the existing facility showed a peak draw of 323 kW, or $15W/sf$ – this includes chiller energy and exhaust fan energy (two large users that don't contribute to internal gains)
- Careful examination of the electricity data outside of the cooling season led to the engineer accepting that internal gains likely were between 5 and 7 W/sf
- The revised cooling load was under **100 tons**

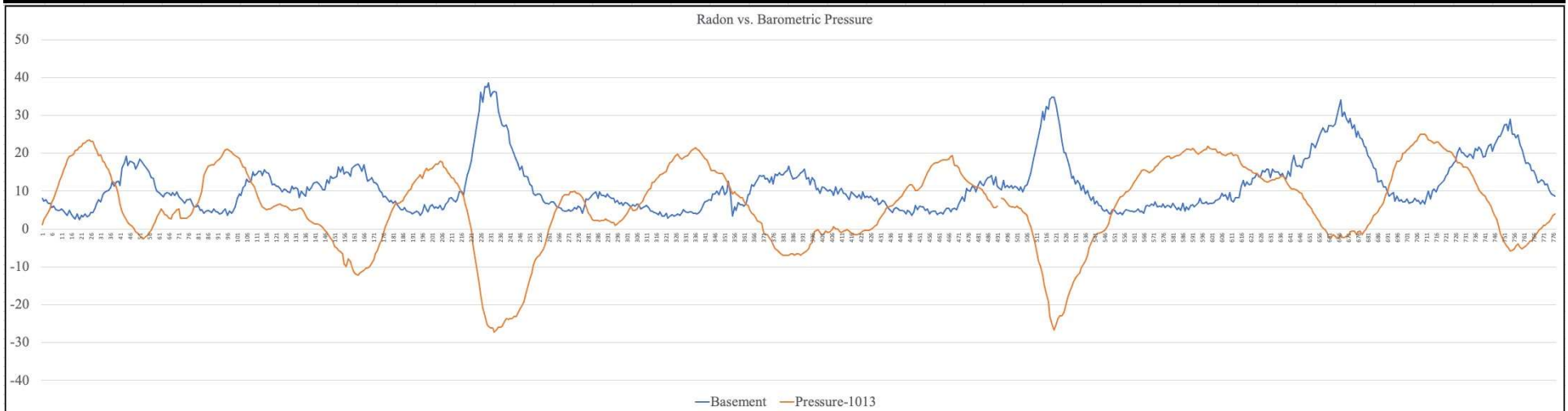


Case #7

Understand cause and effect

The Case of the Varying Radon Levels

I've been trying to understand what causes the radon level in my basement to vary so much. I have correlated it with ΔP between indoors and outdoors, outdoor temperature, and now barometric pressure. I get hourly barometric pressure from the Web, and measure radon with the RadonEye. The low pressure events are storms, so the cause may be rain soaking the ground rather than barometric pressure itself.



Pressure is plotted as (Barometric Pressure – 1013 millibars)

Case #8

Understand cause and effect

The Case of The Mystery CO2



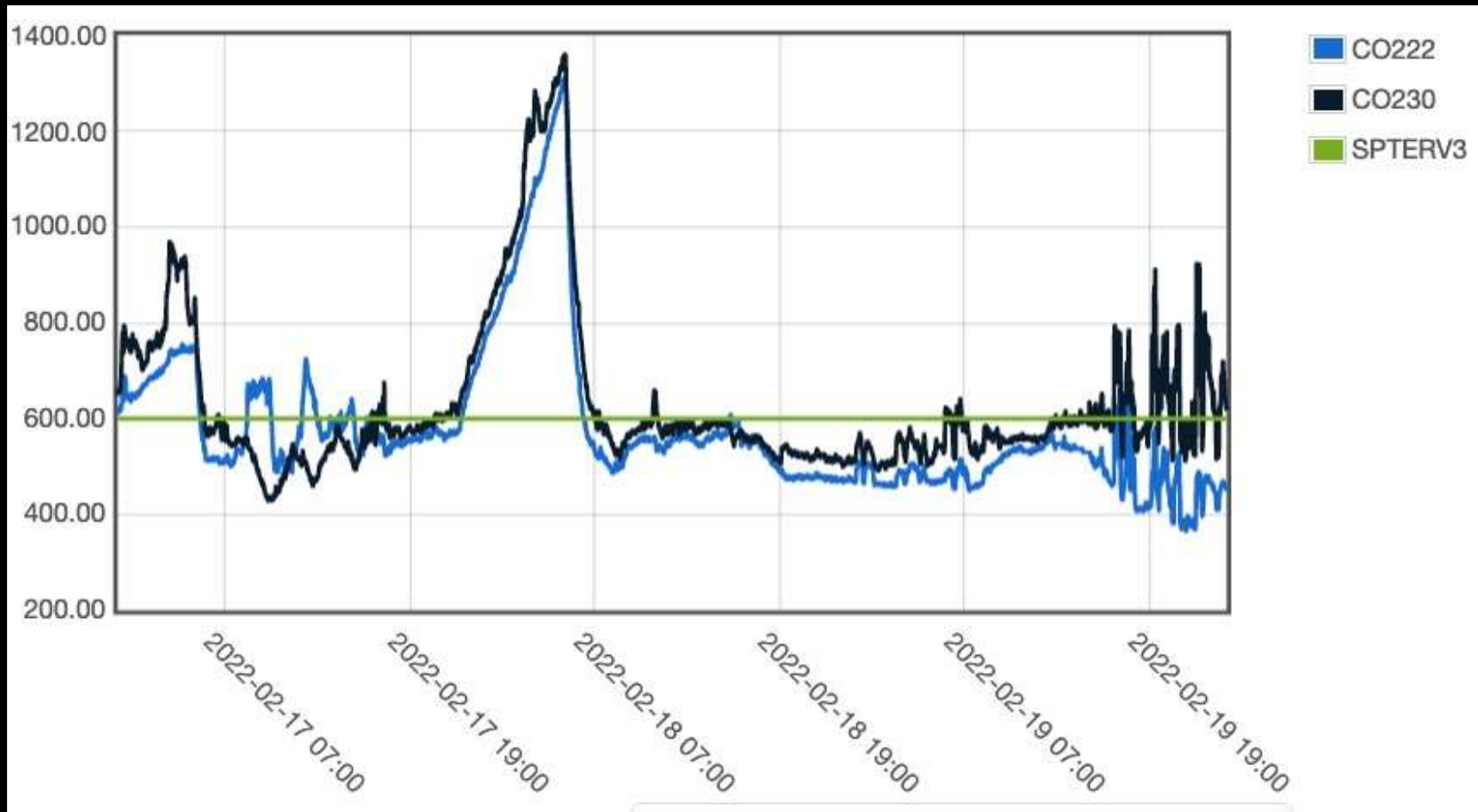
The Case of The Mystery CO2



The Case of The Mystery CO2

- New 10,000 sf Early Childhood Center on Martha's Vineyard
- Demand controlled ventilation with Renewaire ERVs based on CO2
- Mitsubishi ASHPs with heat recovery for heating and cooling
- Ducted UltraAire dehumidifiers for separate humidity control
- ERVs are enabled 5 am – 10 pm
- Dehumidifiers are enabled 10 pm – 5 am and use the same duct work
- eGauge monitoring system
- Watching the building as it was occupied in late Fall, we noticed that CO2 was rising in the rooms on some nights when the ERVs were off and there were no people in the building
- We put a Telaire CO2 sensor and a Hobo logger in place, first in a mechanical attic to see if the CO2 was offgassing from open cell foam

The Case of The Mystery CO2



The Case of The Mystery CO2



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