Facility Profile

Building Basics:

Installation:	---	RCx POC:	---
Building Name:	---|	Building #:	###
Building Age:	2014	Total SF:	106,000
Usage Type:	GIB (Instructional)	CAT CODE:	17120

Utility Data:

Utility Type	Supplier/ Distributor	Rate	Annual Use	Annual Cost	EUI	Benchmark EUI	Benchmark Source
Electricity:	Pacific Gas & Electric	$0.22/kWh	503,857 kWh	$110,850	16.2 kBtu/SF	17.3 kBtu/SF	CBECS 2012
Gas:	Pacific Gas & Electric	$1.10/therm	13,227 therms	$14,550	12.5 kBtu/SF	25.2 kBtu/SF	CBECS 2012
Total:			3,042 MMBtu	$125,400	28.7 kBtu/SF	39 kBtu/SF	Bldg Performance Database

Describe Building Systems Targeted:

☑ Air-side:	5 VAV AHUs with economizers, RFs, and some PH	☑ Additional Zone HVAC:	~250 VAV RH boxes, bathroom exhaust, some IT DX
☑ Cooling:	primary only w/ 155-ton Trane air-cooled screw chiller	☑ Lighting:	mostly 4' 2-lamp T8s on occ sensors, UNK exterior lights
☑ Heating:	non-condensing boiler, 5:1 turndown, UNK config	☑ Special Usage Loads:	~15 Energy Star vending machines
☑ Domestic Hot Water:	10 electric water heaters, ~50 gal ea	☑ Other:	35,000 gallon non-potable water system

Building Control System:

☑ Mech Rm DDC — Controllers: Distech ECLs

☑ Zone-level DDC — Controllers: Distech EC-VAVs

☑ UMCS — Make/ Model: Plexus Altitude

Able to: ☑ View Graphics ☑ Create/Download Trends ☑ Change Schedules ☐ Manage Alarms

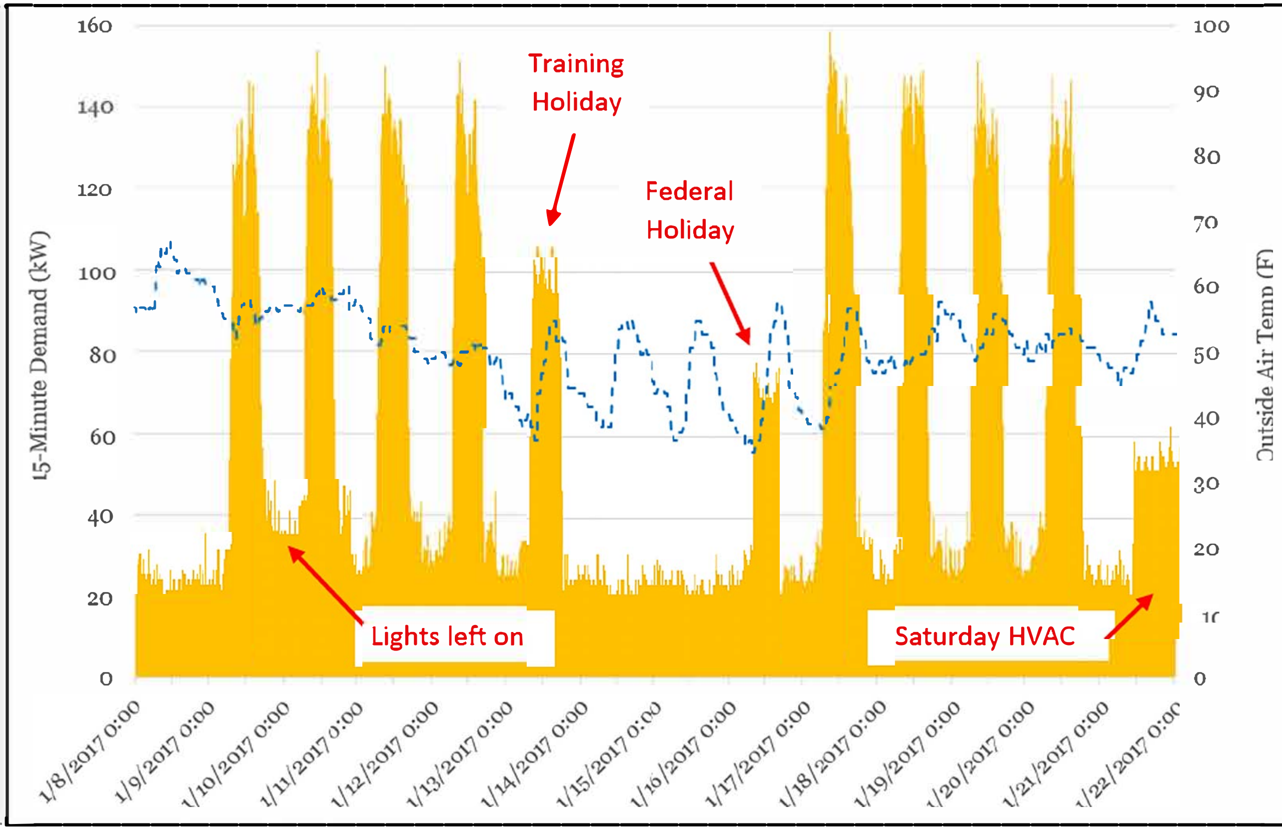
Data Available:

Utility Data:	☑ Monthly Billing Data	☑ Private Interval Data	☐ MDMS Data	☑ DDC Meter Data
Construction Docs:	☑ As-Builts	☑ TAB Report	☐ PVT Report	☑ Points Schedules
O&M Data:	☑ Equipment Manuals	☑ Service Request History	☐ FUS Drawings	☐ BUILDER Data

Primary RCx Goals:

1. Further minimize EUI with emphasis on kWh and kW savings
2. Implement and test additional on-demand HVAC sequences
3. Solve reported controls anomalies and address specific occupant/O&M complair

Meter Data Analysis



Use your meter data to any answer the following questions as applicable:

1	What does your data indicate about daily load profiles?	Typical operating hours appear to be approx 6:30am-4:30pm M-F. Occupied, unoccupied, holiday, lunchtime, and several end-system loads are observable.
2	How about seasonal profiles?	Not enough interval data to observe seasonal changes, however this 2-week period occurs during very typical weather for this area. Unoccupied starts from low temp should not occur and warm-up times should not be at max.
3	How is energy used on weeknights, weekends, and holidays?	Most nights and weekends use baseload levels of energy, however unscheduled HVAC starts, lights left on, and all-night exterior lights are observable. It appears that holiday scheduling is not in use.
4	What are some base load, peak load, and average load values you see?	Baseload: ~20kW; Peak loads: ~140-150 kW (for this typical weather); averaged occupied load: ~130 kW; unoccupied HVAC: 50-70kW; lunch/student plug-loads: ~20-40 kW; Uncontrolled interior lighting load: ~15 kW; exterior lighting load: < 5kW
5	Are there any potential RCx opportunities you can identify?	High priority: holiday scheduling; repair weekend HVAC scheduling/enables; on-demand HVAC enables; Lower priority: lighting occ sensors, exterior lighting timeclocks, improved warm-up optimization

Pic Sheet

Use this sheet to insert picture of your RCx Building or equipment and add additional pages as necessary to fully represent your target systems:

Photo 1 Title:	Bldg ### Exterior

Pic Sheet

Photo 2 Title: Bldg ### Overhead (with system notations)

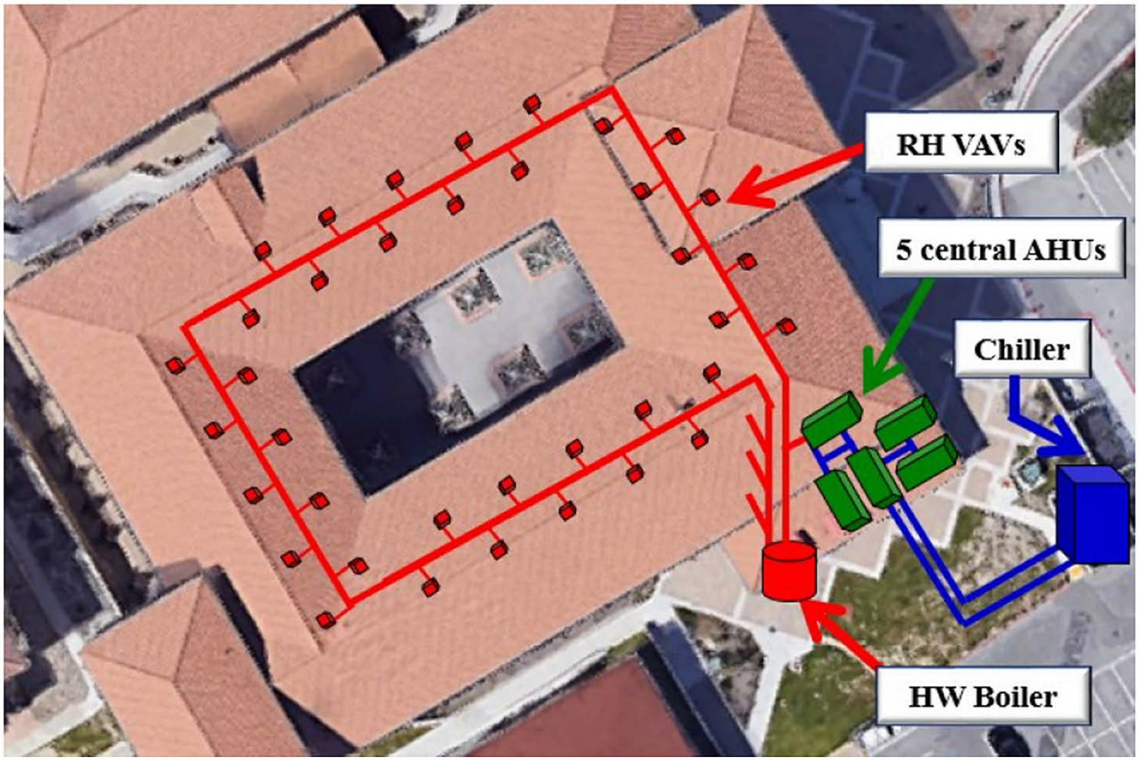
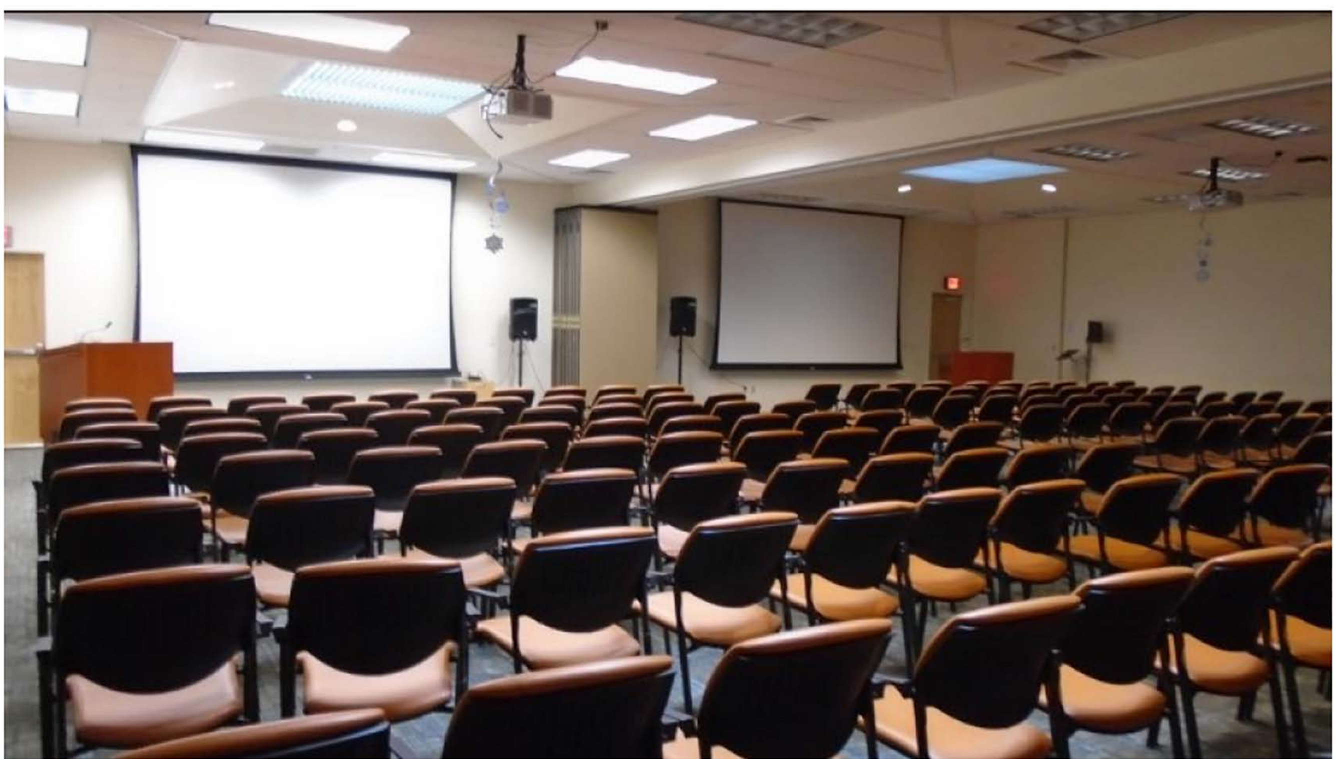


Photo 3 Title: Bldg ### Mech Rm AHU

Pic Sheet

Photo 4 Title: Bldg ### Typical Classroom Zone

Photo 5 Title: Bldg ### Auditorium Zones



Pic Sheet

Photo 6 Title: Bldg ### Chiller

Photo 7 Title: Bldg ### Boiler

Pic Sheet

Photo 8 Title: Bldg ### Typical VAV Box

Photo 9 Title: Bldg ### Auditorium AHU (with PH coil)

Pic Sheet

Photo 10 Title: Bldg ### Typical Electric DHW Heater

Photo 11 Title: Bldg ### Lighting Zones

Pic Sheet

Photo 12 Title: Bldg ### Interior Courtyard (2nd floor)

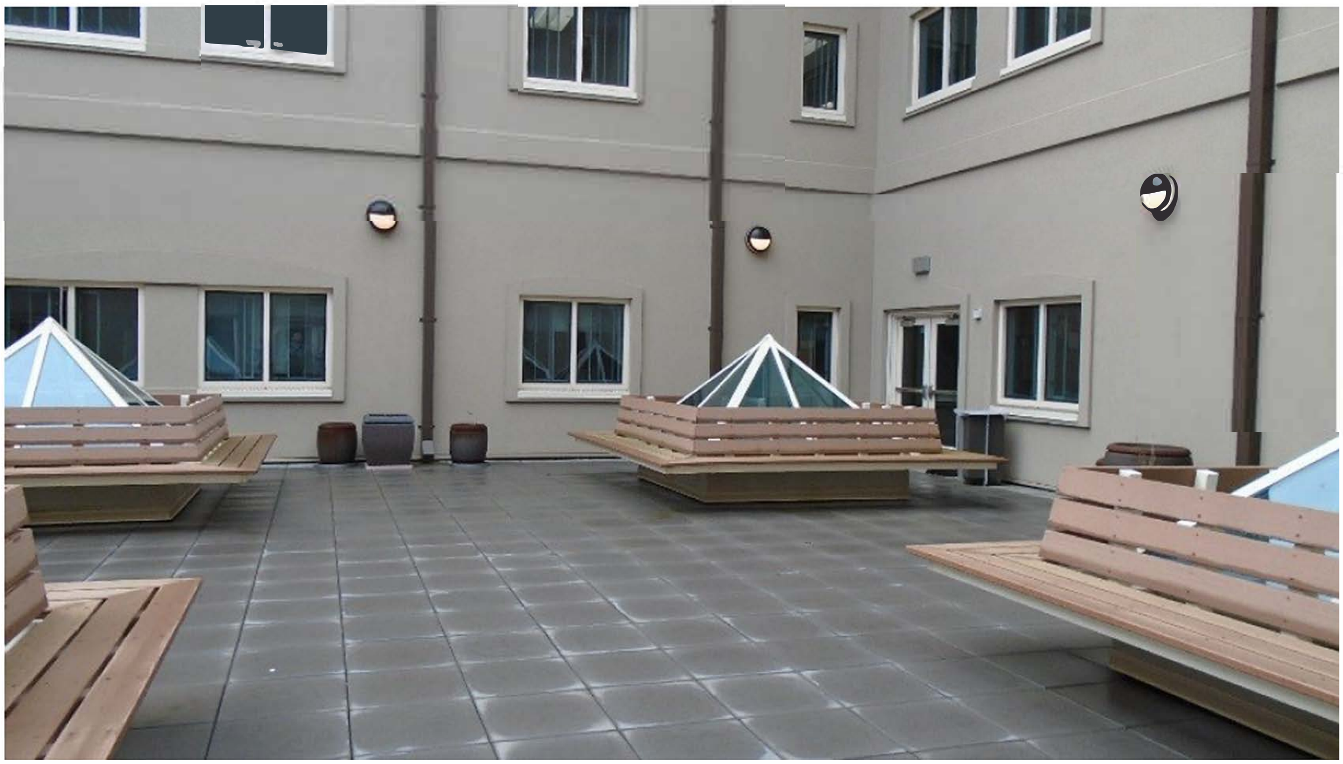


Photo 13 Title: Bldg ### Typical Stairwells

Pic Sheet

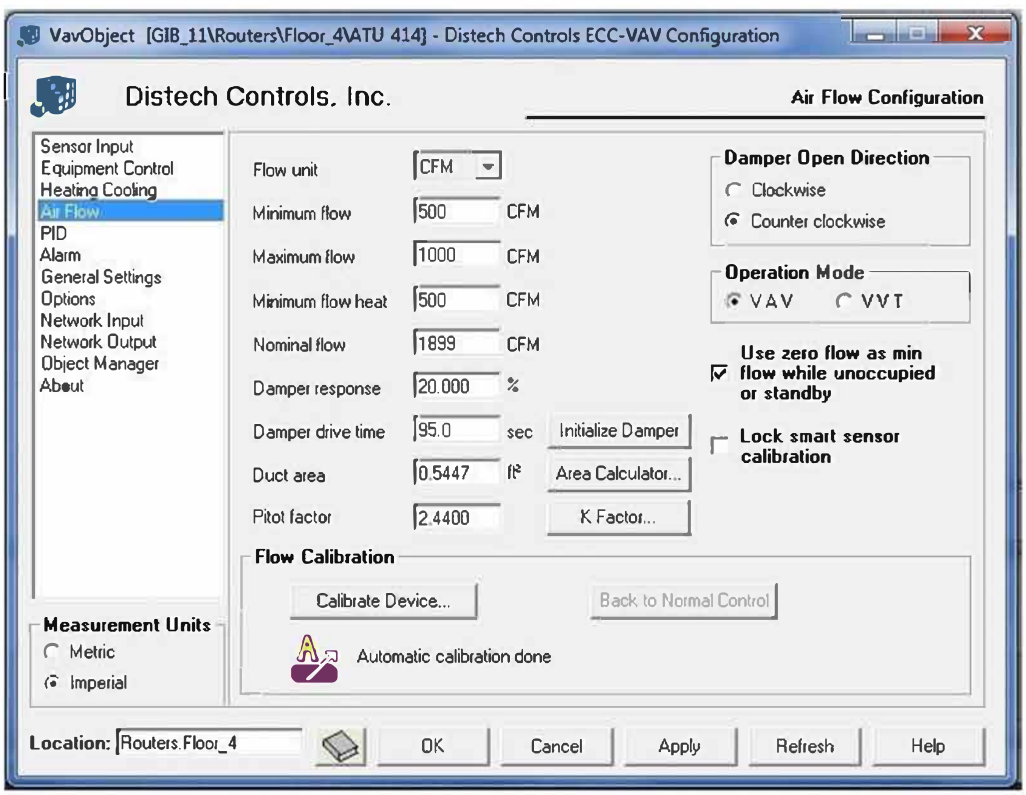
Photo 14 Title: Bldg ### Typical Vending Machines

Photo 15 Title: Bldg ### Typical HVAC Controls Cabinet

Pic Sheet

Photo 16 Title: Bldg ### Local UMCS

Photo 17 Title: Bldg ### Typical VAV Box Config Screenshot



Pic Sheet

Photo 18 Title: Bldg ### Typical BCS Scheduling Screenshot

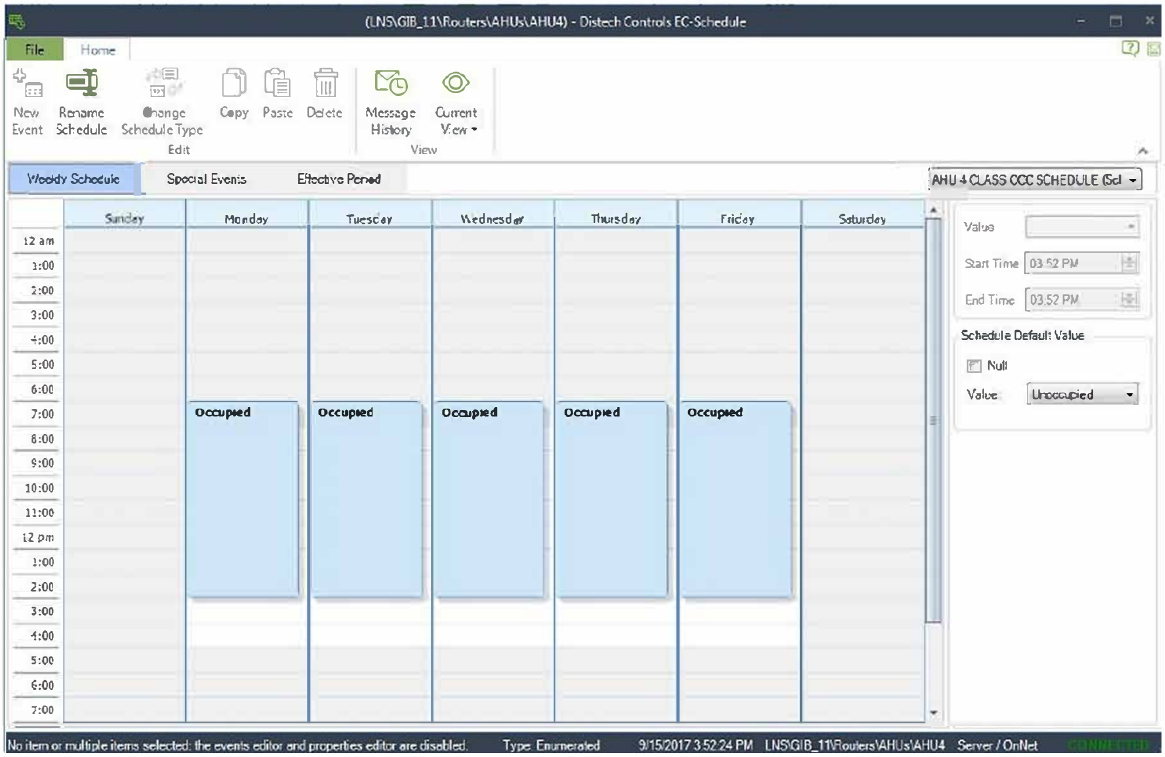


Photo 19 Title: Bldg ### Typical Stat Wiring (includes CO2 output)

Pic Sheet

Photo 20 Title: Bldg ### Typical Bathroom Layout

Photo 21 Title: Bldg ### Typical Final Filter (bag-type)

Pic Sheet

Photo 22 Title: Bldg ### Broken HWS Flow Switch

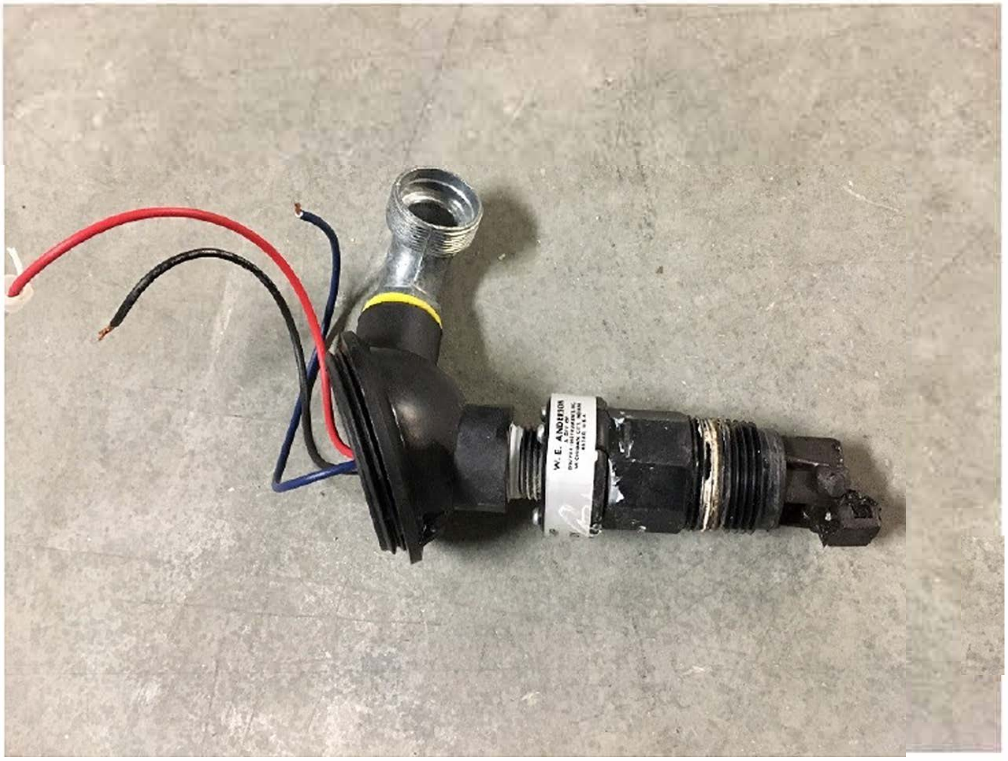


Photo 23 Title: Bldg ### Failing Roof Insulation

Pic Sheet

Photo 24 Title: Bldg ### Screenshot of UMCS Tools

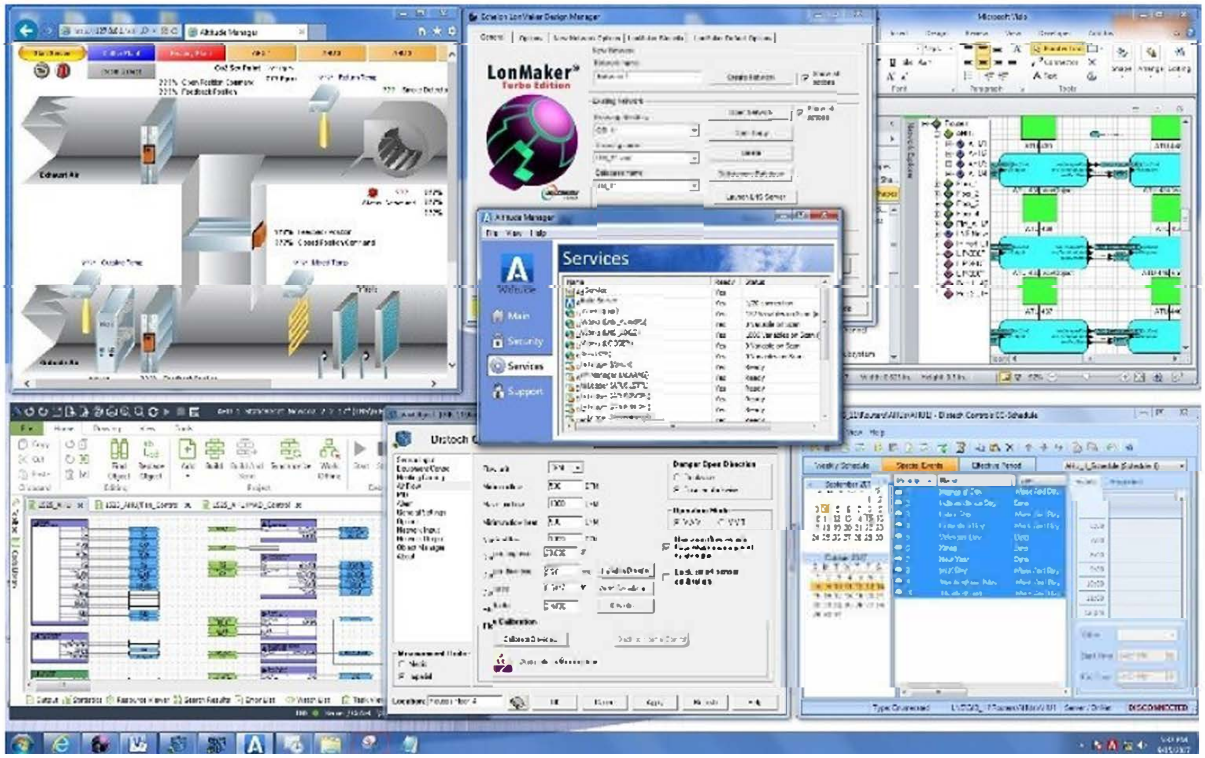


Photo 25 Title: Bldg ### Typical Economizer Config

Pic Sheet

Photo 26 Title: Bldg ### Improper Freezestat Install

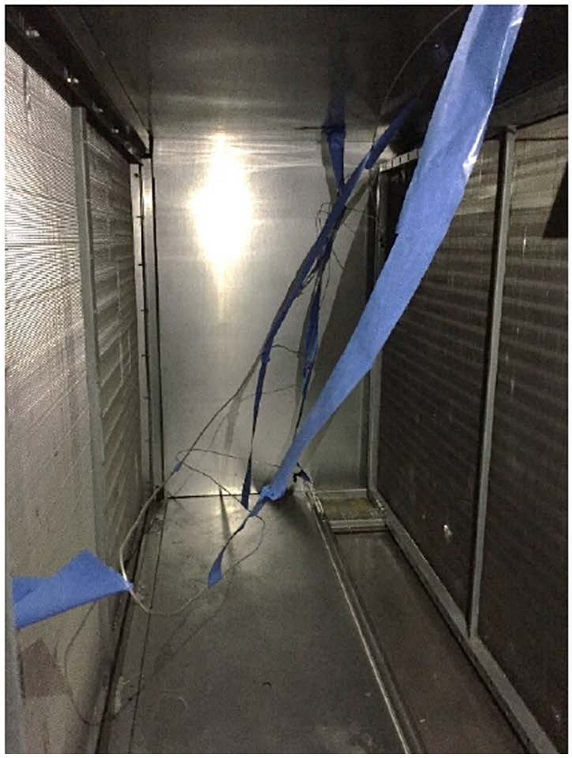
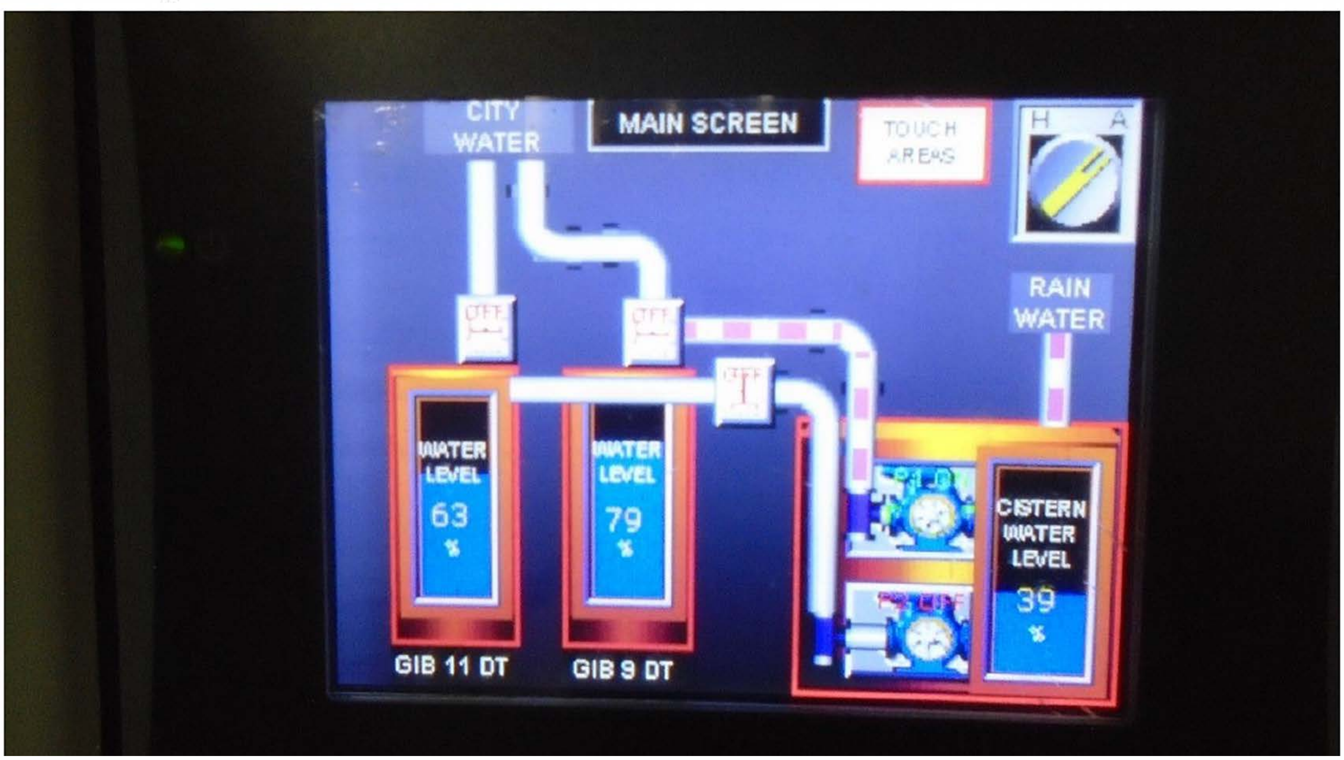


Photo 27 Title: Bldg ### AHU Discharge (high pressure drop)

Pic Sheet

Photo 28 Title: Bldg ### HWP VFD

Photo 29 Title: Building XXX Non-Potable Water System Interface



Equipment Inventory

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Building: ________##________ Date: __2/2/17__

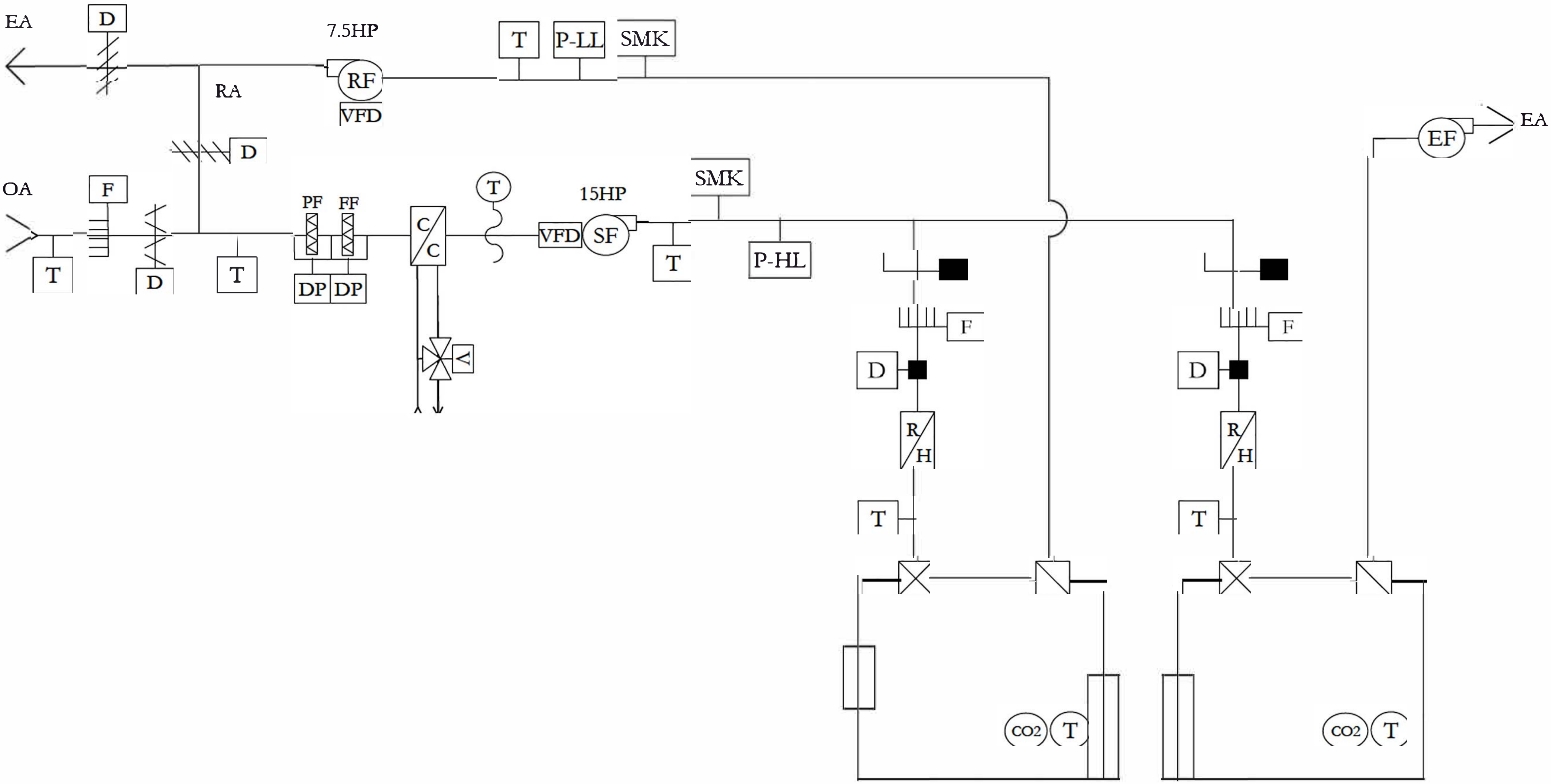
Inventory POC: ________-----_________

System Name	Equipment Name	Location	Make / Model	Output Capacity	Input Capacity (or Efficiency)	Electrical Info	Notes
AHUs	supply fan	mech room, discharge panel	Trane CSAA030UAC00	10,00-25,000 CFM	-	-	20-35% min OA
AHUs	SF motor	mech room, discharge panel	Baldor Super E	15-40 HP	premium	460V/3Ph (30A)	1770 RPM, "inverter-ready"
AHUs	return fan	mech room, discharge panel	Trane CSAA030UAC00	17,180 CFM (TAB)	-	-	-
AHUs	RF motor	mech room, discharge panel	Baldor Super E	7.5-15 HP	premium	460V/3Ph (20A)	1770 RPM, "inverter-ready"
AHUs	SF VFD	mech room, AHU cabinet					
AHUs	RF VFD	mech room, AHU cabinet					
AHUs	AHU PFs	mech room, inlet panel	Air Handler	MERV 7	-	-	pleated-type
AHUs	AHU FFs	mech room, inlet panel	X09010376-03		95%	-	bag-type
AHUs	prgm cntrlr	mech room, AHU cabinet	Distech ECL-650	12 UO (2 free)	16 UI (0 free)	24V	LCD display, LonMark
AHUs	prgm cntrlr	mech room, AHU cabinet	Distech ECx-410	12 UO (12 free)	12 UI (4 free)	24V	analog HOA switches, LonMark (1 ea add'l I/O for AHU-5)
AHUs	HWS LDP	mech room, AHU cabinet	Distech EC-Display	-	-	24V	no schedule use
AHUs	confg cntrlr	ceiling tiles/attic	Distech ECC-VAV	-	-	24V	pressure-independent, LonMark
AHUs	zone stat	wall mount	Distech EC-Sensor	-	-	-	Temp, SP, override
AHUs	zone CO2	wall mount	Dwyer CDT-2W50	-	-	-	CO2 OUT only
ChWS	Ch	mech yard	Trane RTAC 1554	155 tons	~12 EER	460V/3Ph (250A)	15% turndown (2 screw units), no HGB, evap min/max: 200/750 GPM
ChWS	ChWP	mech room	B&G 1510 7.125BF	275 GPM, 46' (TAB)	73%	5 HP (TAB)	non-overloading. 70% open TDV
ChWS	ChW motor	mech room	Baldor Super E (EM3311T)	7.5 HP	91%	208V/3Ph (20A)	1770 RPM, "inverter-ready"
ChWS	prgm cntrlr	mech room, chiller cabinet	Distech ECL-650				

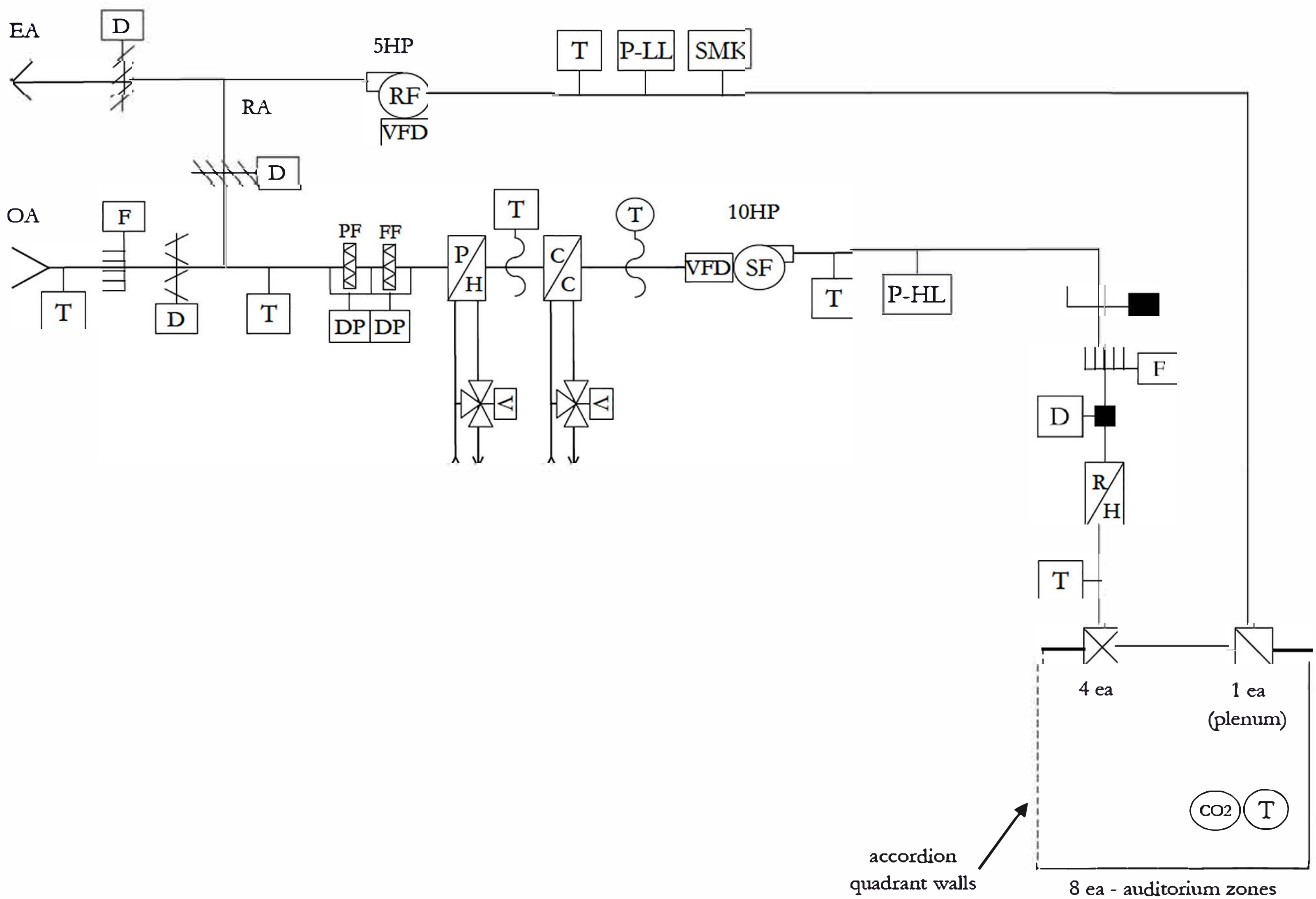
Equipment Inventory

System Name	Equipment Name	Location	Make / Model	Output Capacity	Input Capacity (or Efficiency)	Electrical Info	Notes
HWS	HWS LDP	mech room, boiler cabinet	Distech EC-Display	-	-	24V	no schedule use
HWS	B	mech room	Parker Boiler G2640RL	2,165 - 820 MBH	82%	2 HP VFD blower	modulating, non-condensing
HWS	HWP	mech room	B&G 1510 2BC9.5BF	218 GPM, 65' (TAB)	65%	5 HP (TAB)	non-overloading. 80% open TDV
HWS	HWP motor	mech room	Baldor Super E (EM3311T)	7.5 HP	91%	208V/3Ph (20A)	1770 RPM, "inverter-ready"
HWS	HWP VFD	mech room					
HWS	prgm cntrlr	mech room, boiler cabinet	Distech ECL-650				
HWS	HWS LDP	mech room, boiler cabinet	Distech EC-Display	-	-	24V	no schedule use
DHW	WH-1, 2, 4-9	bathroom janitor closets	Bradford White PHCC (50 gal)	3 x 6 kW elements	~100%	480V/3Ph (22A)	125F setpoint
Vending	VM-1	hallways	(dry only)		E Star?		Qty: 4, non-refrigerated
Vending	VM-2	hallways	(dry & bottles)		E Star?		Qty: 4, refrigerated
Vending	VM-1	hallways	Coca Cola		E Star?		Qty: 2, refrigerated
Vending	VM-2	hallways	Pepsi		E Star?		Qty: 4, refrigerated

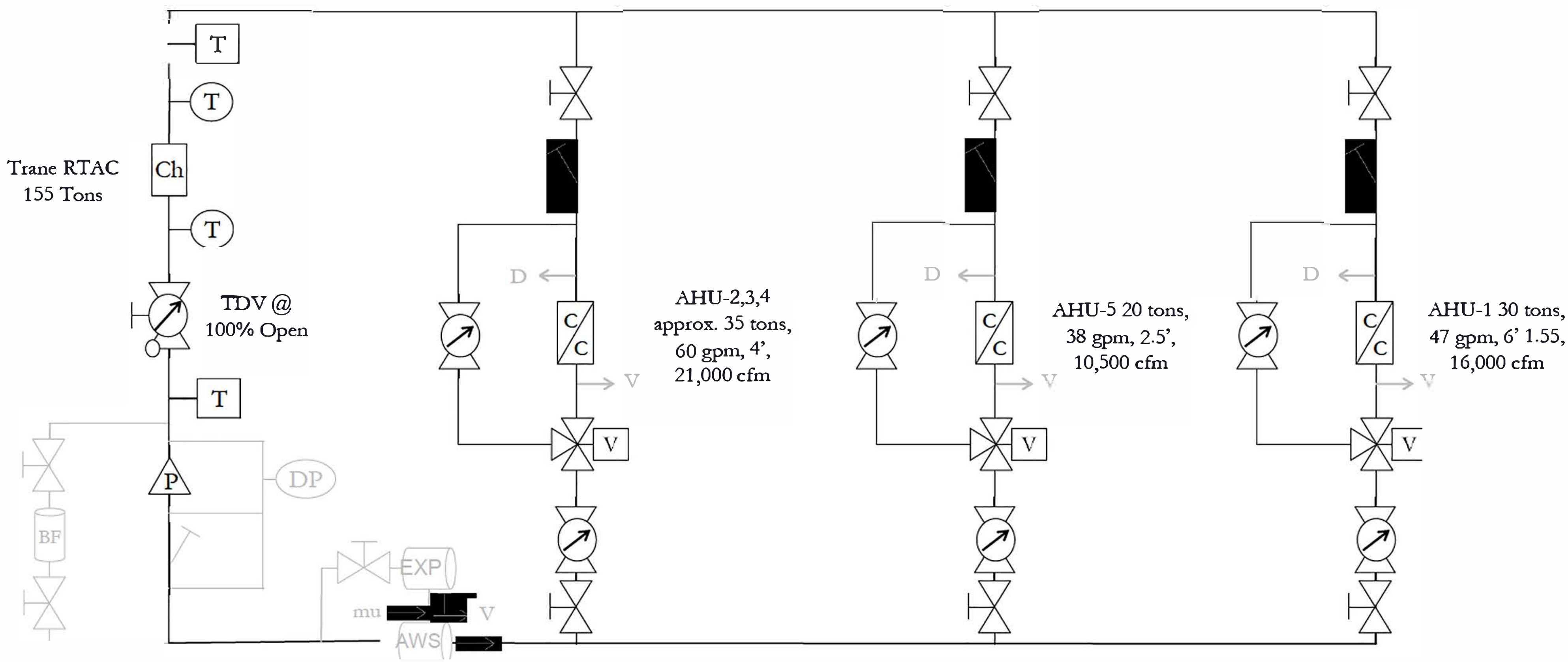
System Diagram - Typical AHU



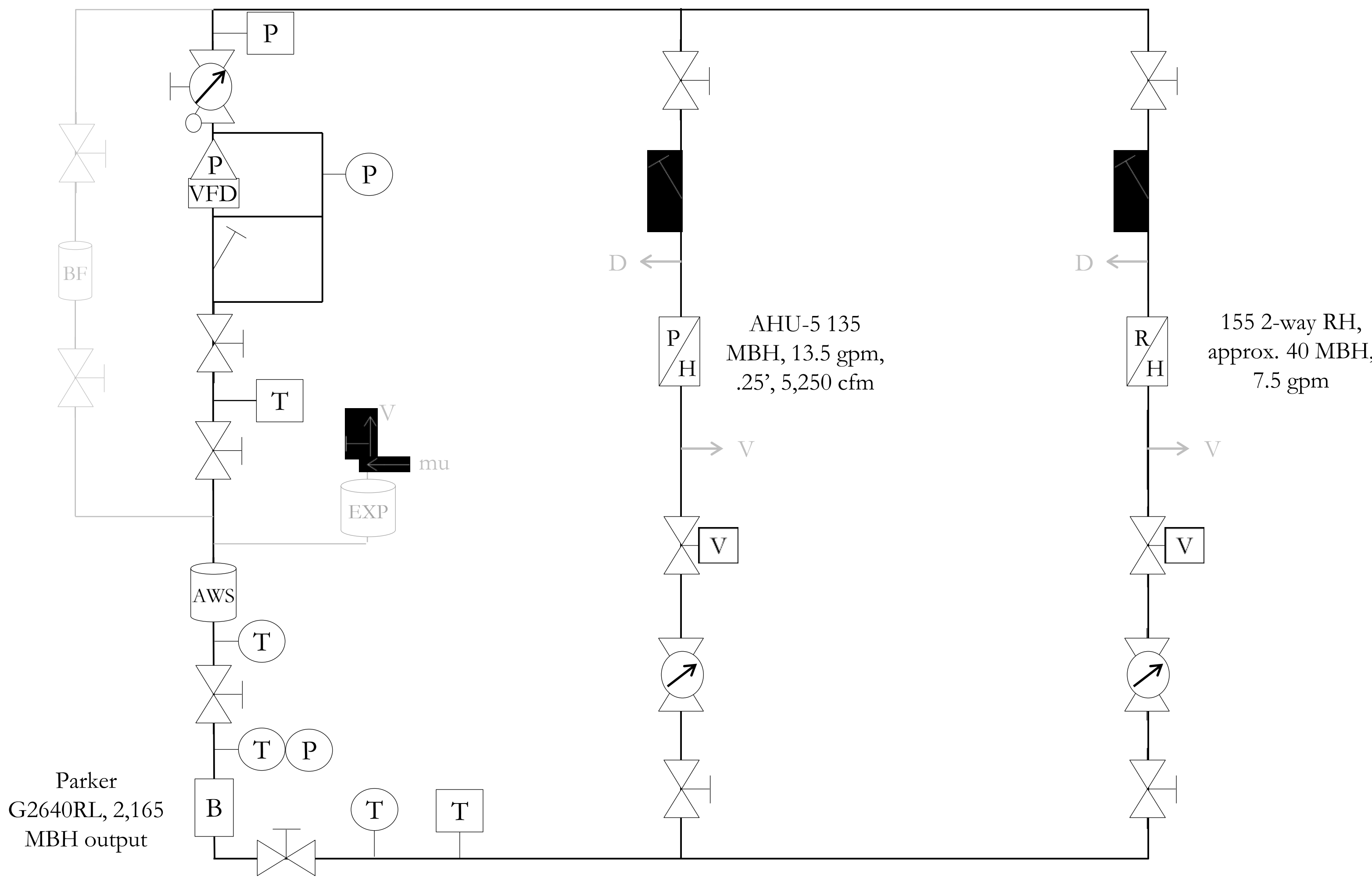
System Diagram - AHU-5 (special zones)



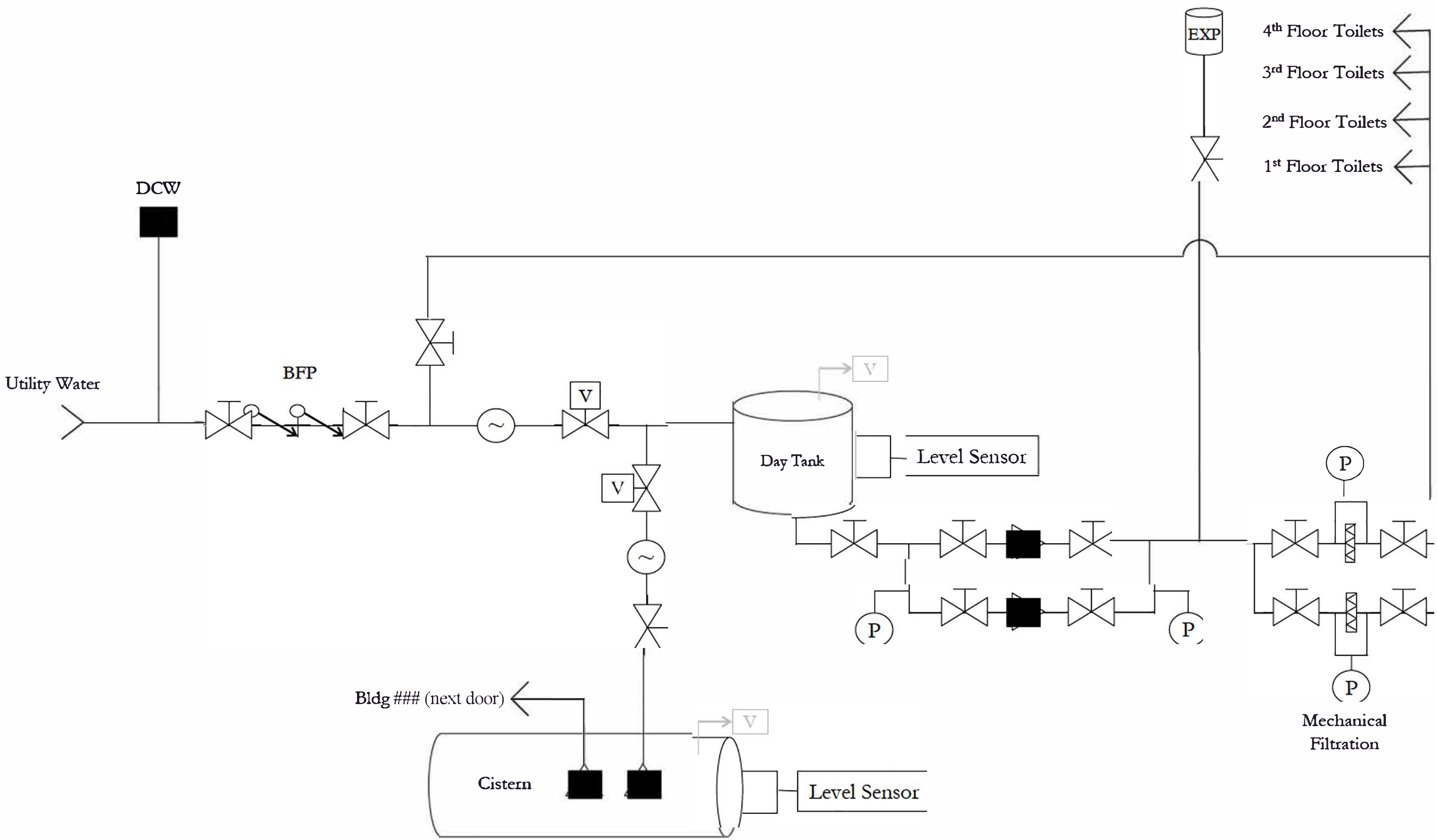
System Diagram - ChWS



System Diagram - HWS



Non-Potable Water System Diagram



ECM List

Building: ##

Date: 2/2/17

Indicate likelihood of ECM viability: **H** (high), **M** (medium), **L** (low), **!** (Exists wth Problems), **~** (Exists,/Ignore) or **N/A**:

		Scheduling
!	1.1	**HVAC Start-Up Optimization**
L	1.2	HVAC Shut-Down Optimization
H	1.3	**Holiday HVAC Exceptions** (5 existing/expired)
H	1.4	Zone-Level Scheduling
NA	1.5	DHW Return Pump Scheduling
L	1.6	Interior Lighting Circuit Scheduling
M	1.7	Exterior Lighting Circuit Scheduling
L	1.8	Electrical Equipment Scheduling
		Setpoint Value Adjustments
M	2.1	**Adjust zone temperature setpoints**
L	2.2	Adjust zone humidity setpoints
L	2.3	Adjust MAT setpoint (1F SAT offset)
L	2.4	Adjust coil discharge setpoint
H	2.5	Adjust hydronic supply setpoint
L	2.6	Adjust pressure discharge setpoint
M	2.7	Adjust zone CFM setpoints
L	2.8	Adjust lightling levels (delamp)
		Automatic Setpoint Reset Sequences
H	3.1	**Duct Static Pressure Setpoin Reset**
!	3.2	**Supply Air Temperature Setpoint Reset**
!	3.3	Mixed Air Temperature Setpoint Reset
!	3.4	Min OA Flow Setpoint Reset
!	3.5	Zone Flow Setpoint Reset
NA	3.6	Hydronic Storage Temperature Setpoint Reset
L	3.7	Hydronic Pressure Setpoint Reset
M	3.10	**Hydronic Temperature Setpoint Reset**
~	3.11	Zone Temperature/Humitidty Setback
M	3.12	Low-Use Equipment Standby (Vending Machines)
M	3.13	Daylight Sensors
		No-Load Disables
!	4.1	Time-Delay Hydronic Pump Disable
!	4.2	**Outside-Air Boiler/Chiller Lockout**
M	4.3	Valve-Based Boiler/Chiller Lockout
H	4.4	**HVAC Equipment Standby/Override Only**
M	4.5	**HVAC Occupancy Sensors**
H	4.6	Lighting Occupancy Sensors or Timers (stairs/bath)
L	4.7	Exterior Lighting Motion Sensors or Timers
NA	4.8	Electrical Equipment Demand-Only

		Oversized Equipment
M	5.1	**Pump Optimization (Throttle, VFD, or Trim)**
L	5.2	Fan Resheave
L	5.3	Thermal Flywheel or Buffer Tank
H	5.4	Boiler/Chiller Resizing
L	5.5	Reduce Lighting via Fixture/Bulb Replacement
		Load Reduction
L	6.1	Remove Air-Side Pressure Drop (AHU disch fittings)
L	6.2	Remove Water-Side Pressure Drop (PH coil)
M	6.3	**Simultaneous Heating & Cooling Mitigation**
L	6.4	Envelope Entry Improvements
L	6.5	Decommission Unused Electronic Equipment
		Variable Volume
NA	7.1	**Constant to VAV AHU Retrofit**
NA	7.2	VAV Multizone or Dual Duct Retrofit
M	7.3	Return/Relief Fan Optimization
L	7.4	Variable Exhaust or Flow Hood Retrofit
!	7.5	Variable Hydronic (Pump/System DP)
L	7.6	Variable Hydronic (OA or Valve-Based)
NA	7.7	Primary-Secondary Reconfiguration
		BAS Repairs
H	8.1	**Correct BAS Communication Errors**
M	8.2	Correct BAS Logic Errors (messy GFX logic)
H	8.3	Calibrate Sensors: Temp, Pressure, Occ, or CO2
!	8.4	Relocate/Replace Sensors (rebind OAT to N sensor)
H	8.5	Repair Actuators: Damper, Valve, or Relay
M	8.6	Control Loop Tuning
M	8.7	BAS Replacements or Upgrades
		Equipment Efficiency
L	9.1	Drive Upgrades: Motor, Pump, Fan, VFD, or Belt
NA	9.2	Maximized Condensing Boiler Operations
L	9.3	Optimized Chiller Staging
M	9.4	Zone-level 1st Stage HVAC
H	9.5	Economizers: Optimized Enable/Disable
H	9.6	DHW Heater: Condensing/Instant/Utility Switch
H	9.7	Lighting Bulb Type Retrofit (LED project planned)

ECM List

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Human Behavior & Occupant Comfort

H	11.1	Inadequate Signage or Instruction
M	11.2	Occupant Start-up/Shutdown Procedures
L	11.3	Occupant Bypass of Facility Systems
H	11.4	Missing HVAC/Lighting Override Capabilities
L	11.5	Energy Concervation Incentivization
NA	11.6	Thermal Comfort Complaints

Water Savings

M	11.1	Utility-Level Leak Detection
L	11.2	HVAC Makeup Water Tracking
NA	11.3	Irrigation Improvements
H	11.4	Optimize Non-Potable Water Flows
NA	11.5	Mitigate Evaporative Cooling Water Losses
L	11.6	Process/Cleaning Process Imprvements

O&M Processes

H	10.1	Filter Replacements (single 3M HE filter)
L	10.2	Equipment Tuning/Treatment/Blowdown
NA	10.3	**MCC/Controller H-O-A or DDC Overrides**
L	10.4	Gaps in Staffing, Training, or Workflow

Misc

	12.1	
	12.2	
	12.3	
	12.4	
	12.5	
	12.6	
	12.7	
	12.8	

Preliminary RCx Measures

POC: ---

Date: 4-Apr-17

#	System	Potential ECM	Savings Range		ROM Cost Est	Monitor-ing Plan	Funct-ional Test	Status
1	all HVAC	holiday exceptions	$750	$1,000	$0		X	Implemented
2	all air-side	adjust thermostat setpoints	$100	$250	$0			Implemented
3	all air-side	duct static pressure reset	$2,000	$4,000	$0	X		Implemented
4	AHU-1, 2, 3, 4	CO2-based ventilation reset removal	$100	$250	$0	X		Implemented
5	BAS	restore front-end functionality	$0	$0	$2.5K		X	Implemented
6	hot water	pump time-delayed disable	$100	$100	$0	X	X	Implemented
7	AHU-5	average common zone systems	$100	$250	$0	X	X	Recommended
8	AHU-5	demand-controlled ventilation	$2,250	$3,000	$0	X	X	Recommended
9	AHU-1, 2, 3, 4	zone scheduling	$700	$1,200	$0		X	Recommended
10	all air-side	adjust zone CFM setpoints	$800	$1,400	$0	X		Recommended
11	all HVAC	start-up optimization adjustments	$750	$1,300	$0	X		Recommended
12	AHU-5	simultaneous heating/cooling	$450	$900	$0	X		Recommended
13	all air-side	optimize filter systems & replacements	$500	$700	$0	X	X	Recommended
14	all air-side	balance supply/return fan CFM	$250	$500	$0	X	X	Recommended
15	all air-side	optimize economizer setpoints	$100	$250	$0	X	X	Recommended
16	all air-side	supply temperature reset adjustments	$100	$250	$0	X		Low Priority
17	hot water	reduce boiler cycling	$100	$250	$250	X	X	Recommended
18	hot water	boiler outside air lockout adjustment	$100	$250	$0	X	X	Recommended
19	chilled water	pump optimization	$100	$250	$250		X	Recommended
20	lighting	stairwell daylight/motion sensors	$1,500	$2,000	$2.5K	X		Recommended
21	lighting	exterior lights scheduling	$600	$1,000	$250			Recommended
22	lighting	bath/entry/supply rm occ sensors	$600	$1,000	$2.5K	X		Recommended
23	DHW	instant 1st floor DHW heaters	$250	$500	$500	X	X	Recommended
24	cistern system	optimize non-potable flows	$600	$1,400	$0	X		Recommended
25	plug-loads	Energy Star vending settings	$100	$250	$0	X		Recommended
26	hot water	temperature setpoint reset adjustments	$100	$250	$0			Low Priority
27	chilled water	valve-based chiller lockout	-$250	$0	$0			Low Priority
28	comms rooms	zone-level 1st stage HVAC	$100	$250	$0			Low Priority
29	lighting	T8 to linear LED retrofits	$15,000	$20,000	$350K			Low Priority

Monitoring Plan

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Building: ______##______ Date: __5/30/17__
Monitoring Plan POC: ___-----_____

ECM	System	Location	Type	Point Name or Logger ID	Trend Interval	Trend Legnth	Dates			Status	Notes
							Launch	Download 1	Download 2		
7	AHU-5	160H temp SP	BAS	160H temp SP	5 min	4 wks		4 wks later			to check averaging
3	AHU-5	critical VAV box	BAS	avg damper %	15 min	4 wks					to track DSPR
10	AHU-1	AHU SF flow	BAS	SF-F	5 min	4 wks					do AHU's VAV?
11	AHU-?	N wall OA sensor	Temp Logger		5 min	4 wks					good global temp?
20	Ex Ltg	Main Stair, Floor 2	Occ/lt Logger		COV	2 wks					
10	AHU-5	AHU supply flow	BAS	SF-F	5 min	4 wks					do AHU's VAV?
8	AHU-5	160F zone CO2	BAS	160F zone CO2	5 min	4 wks		4 wks later			sensor checks
3	AHU-4	critical VAV box	BAS	max damper %	15 min	4 wks					to track DSPR
8	AHU-5	160D zone CO2	BAS	160D zone CO2	5 min	4 wks		4 wks later			sensor checks
6	HWS	boiler status	BAS	boiler status or S/S	COV	1 wk					check HWP runtime
7	AHU-5	160F temp SP	BAS	160F temp SP	5 min	4 wks		4 wks later			to check averaging
7	AHU-5	160E temp SP	BAS	160E temp SP	5 min	4 wks		4 wks later			to check averaging
15	AHU-3	MAT filter face 7	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
7	AHU-5	160A temp SP	BAS	160A temp SP	5 min	4 wks		4 wks later			to check averaging
18	HWS	spare well HWST	Temp Logger		5 min	4 wks					4-channel + temp probe
7	AHU-5	160C temp SP	BAS	160C temp SP	5 min	4 wks		4 wks later			to check averaging
14	AHU-5	supply flow	BAS	SA-F	1 sec	60 min					15 Hz/min test rate
25	Cisterns	vending mach 3	Plug Logger		1 min	2 wks					WattsUp tool
15	AHU-4	econo temps	BAS	MAT	5 min	4 wks					
20	Ex Ltg	Main Stair, Floor 3	Occ/lt Logger		COV	2 wks					
8	AHU-5	160F min OA SP	BAS	160F min OA SP	5 min	4 wks		4 wks later			sensor checks
15	AHU-3	MAT filter face 1	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
23	DHW	1st flr shower HW	Temp Logger		15 sec	2 wks					4-channel + temp probe
15	AHU-5	econo temps	BAS	OAT	5 min	4 wks					also graph all OATs
14	AHU-2	supply flow	BAS	SA-F	1 sec	60 min					15 Hz/min test rate
8	AHU-5	160H zone CO2	BAS	160H zone CO2	5 min	4 wks		4 wks later			sensor checks
15	AHU-3	econo temps	BAS	OAT	5 min	4 wks					also graph all OATs
13	AHU-1	pre-filter p drop	BAS	PF-P	1 sec	60 min					15 Hz/min test rate
15	AHU-4	econo damper %	BAS	OAD	5 min	4 wks					

Monitoring Plan

ECM	System	Location	Type	Point Name or Logger ID	Trend Interval	Trend Legnth	Dates Launch	Download 1	Download 2	Status	Notes
8	AHU-5	160C min OA SP	BAS	160C min OA SP	5 min	4 wks		4 wks later			sensor checks
4	AHU-1	econo min OA SP	BAS	econo min OA	15 min	4 wks					verify static min OA
22	Ex Ltg	Bathroom 2	Occ/lt Logger		COV	2 wks					
15	AHU-5	MAT filter face 7	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
3	AHU-2	critical VAV box	BAS	avg damper %	15 min	4 wks					to track DSPR
23	DHW	any janitor closet	Amp Logger		15 sec	2 wks					4-channel + 20 amp CT
11	AHU-?	N wall OA sensor	BAS	OAT	5 min	4 wks					good global temp?
15	AHU-5	MAT filter face 3	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
15	AHU-3	MAT filter face 8	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
15	AHU-3	MAT filter face 3	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
13	AHU-5	pre-filter p drop	BAS	PF-P	1 sec	60 min					15 Hz/min test rate
15	AHU-5	econo damper %	BAS	OAD	5 min	4 wks					
15	AHU-4	econo temps	BAS	RAT	5 min	4 wks					
8	AHU-5	160B zone CO2	BAS	160B zone CO2	5 min	4 wks		4 wks later			sensor checks
8	AHU-5	160B min OA SP	BAS	160B min OA SP	5 min	4 wks		4 wks later			sensor checks
7	AHU-5	160G temp SP	BAS	160G temp SP	5 min	4 wks		4 wks later			to check averaging
15	AHU-1	econo temps	BAS	MAT	5 min	4 wks					
15	AHU-5	econo temps	BAS	MAT	5 min	4 wks					
15	AHU-3	MAT filter face 5	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
+	Water	bldg water (util)	BAS	WTR-MTR	15 min	4 wks					to track performance
7	AHU-5	160E zone temp	BAS	160E zone temp	5 min	4 wks		4 wks later			to check averaging
15	AHU-2	econo temps	BAS	MAT	5 min	4 wks					
8	AHU-5	160D min OA SP	BAS	160D min OA SP	5 min	4 wks		4 wks later			sensor checks
15	AHU-1	econo temps	BAS	RAT	5 min	4 wks					
7	AHU-5	160D temp SP	BAS	160D temp SP	5 min	4 wks		4 wks later			to check averaging
7	AHU-5	160F zone temp	BAS	160F zone temp	5 min	4 wks		4 wks later			to check averaging
8	AHU-5	160G zone CO2	BAS	160G zone CO2	5 min	4 wks		4 wks later			sensor checks
15	AHU-3	OAT	Temp Logger		15 sec	1.5 wk					
+	ChWS	ChWP motor	BAS	ChWP-S	COV	4 wks					
15	AHU-4	econo temps	BAS	OAT	5 min	4 wks					also graph all OATs
15	AHU-5	RAT	Temp Logger		15 sec	1.5 wk					pickup RH also
8	AHU-5	160E zone CO2	BAS	160E zone CO2	5 min	4 wks		4 wks later			sensor checks
11	AHU-2	Dean's office temp	BAS	ZN-T	5 min	4 wks					start vs warm-up

Monitoring Plan

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for a safer, better world

ECM	System	Location	Type	Point Name or Logger ID	Trend Interval	Trend Legnth	Dates			Status	Notes
							Launch	Download 1	Download 2		
8	AHU-5	160? Occ/light	Occ/lt Logger		COV	4 wks		4 wks later			meas auditorium occ
7	AHU-5	160H zone temp	BAS	160H zone temp	5 min	4 wks		4 wks later			to check averaging
8	AHU-5	160G min OA SP	BAS	160G min OA SP	5 min	4 wks		4 wks later			sensor checks
8	AHU-5	160? Occ/light	Occ/lt Logger		COV	4 wks		4 wks later			meas auditorium occ
3	AHU-4	critical VAV box	BAS	avg damper %	15 min	4 wks					to track DSPR
25	Cisterns	vending mach 2	Plug Logger		1 min	2 wks					WattsUp tool
15	AHU-3	MAT filter face 2	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
15	AHU-5	econo temps	BAS	RAT	5 min	4 wks					
11	AHU-2	AHU start time	BAS	SF-S	COV	4 wks					start vs warm-up
15	AHU-2	econo temps	BAS	RAT	5 min	4 wks					
13	AHU-3	pre-filter p drop	BAS	PF-P	1 sec	60 min					15 Hz/min test rate
3	AHU-1	critical VAV box	BAS	avg damper %	15 min	4 wks					to track DSPR
11	AHU-3	AHU start time	BAS	SF-S	COV	4 wks					start vs warm-up
3	AHU-3	critical VAV box	BAS	max damper %	15 min	4 wks					to track DSPR
24	Cisterns	607 tank pump	Amp Logger		1 min	4 wks		2 wks			4-channel + 20 amp CT
7	AHU-5	160D zone temp	BAS	160D zone temp	5 min	4 wks		4 wks later			to check averaging
11	AHU-4	AHU start time	BAS	SF-S	COV	4 wks					start vs warm-up
15	AHU-3	RAT	Temp Logger		15 sec	1.5 wk					pickup RH also
23	DHW	Mech rm heater	Amp Logger		15 sec	2 wks					4-channel + 20 amp CT
15	AHU-5	MAT filter face 5	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
10	AHU-3	AHU SF flow	BAS	SF-F	5 min	4 wks					do AHU's VAV?
20	Ex Ltg	Main Stair, Floor 1	Occ/lt Logger		COV	2 wks					
24	Cisterns	613 bldg pump 1	Amp Logger		1 min	4 wks		2 wks			4-channel + 20 amp CT
11	AHU-1	AHU start time	BAS	SF-S	COV	4 wks					start vs warm-up
+	ChWS	chiller status	BAS	Ch-S	COV	4 wks					
18	HWS	spare well HWRT	BAS	HWRT	15 min	4 wks					
18	HWS	spare well HWST	BAS	HWST	15 min	4 wks					
24	Cisterns	613 bldg pump 2	Amp Logger		1 min	4 wks		2 wks			4-channel + 20 amp CT
8	AHU-5	160? Occ/light	Occ/lt Logger		COV	4 wks		4 wks later			meas auditorium occ
11	AHU-3	hallway temp	BAS	ZN-T	5 min	4 wks					start vs warm-up
17	HWS	flue temp	High T Logger		5 sec	4 dys					+ thermocouple probe
7	AHU-5	160C zone temp	BAS	160C zone temp	5 min	4 wks		4 wks later			to check averaging
+	ChWS	chiller panel	Power Meter		15 sec	2 wks					Dent tool

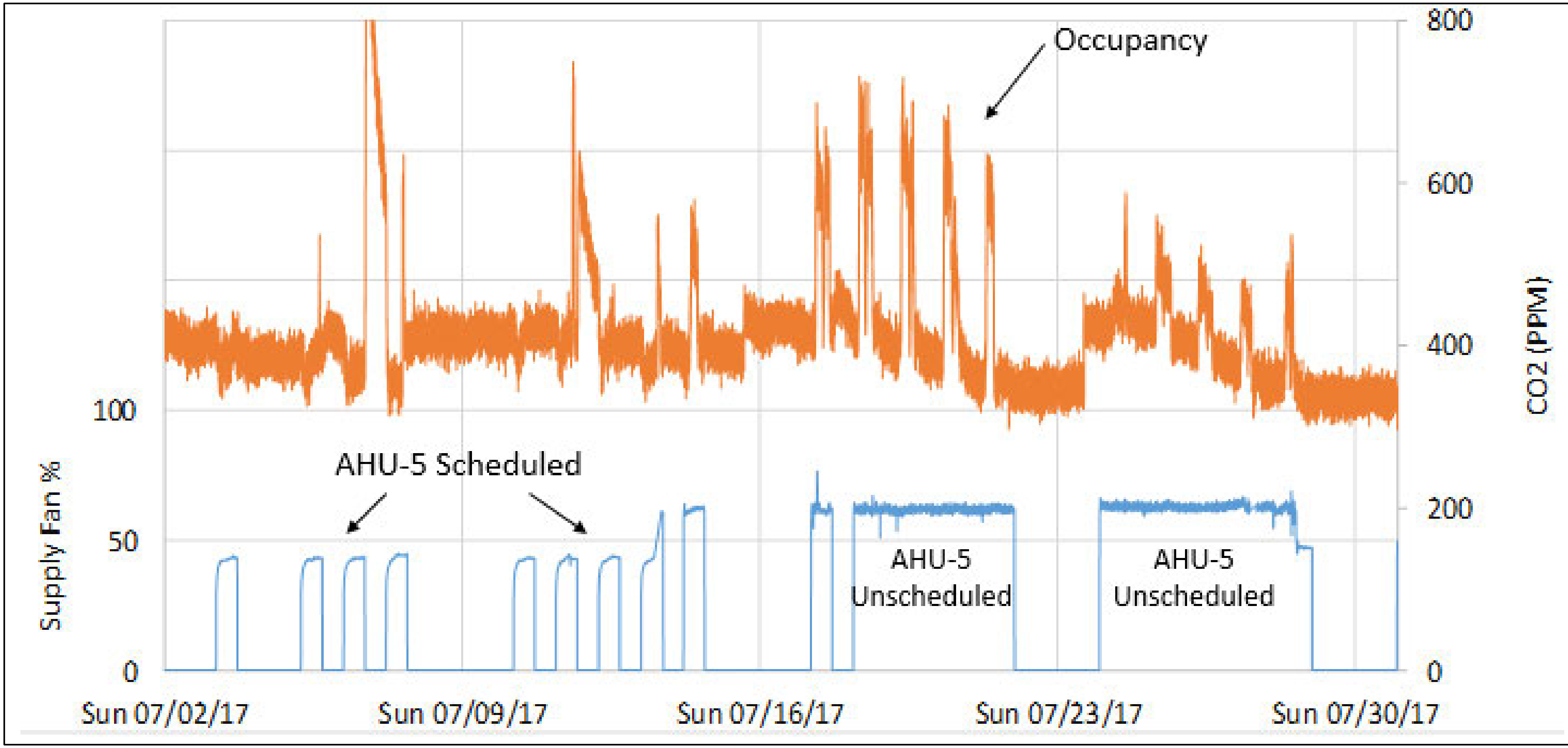
Monitoring Plan

ECM	System	Location	Type	Point Name or Logger ID	Trend Interval	Trend Legnth	Dates			Status	Notes
							Launch	Download 1	Download 2		
12	AHU-5	Preheat discharge	BAS	PH-T	15 min	4 wks					start vs warm-up
10	AHU-4	AHU SF flow	BAS	SF-F	5 min	4 wks					do AHU's VAV?
8	AHU-5	160? zone CO2	CO2 Logger		5 min	4 wks					sensor checks
8	AHU-5	160H min OA SP	BAS	160H min OA SP	5 min	4 wks		4 wks later			sensor checks
+	Bldg	elec main panel	Power Meter		15 sec	2 wks					Dent tool
4	AHU-3	econo min OA SP	BAS	econo min OA	15 min	4 wks					verify static min OA
7	AHU-5	160A zone temp	BAS	160A zone temp	5 min	4 wks		4 wks later			to check averaging
15	AHU-3	econo temps	BAS	MAT	5 min	4 wks					
11	AHU-4	hallway temp	BAS	ZN-T	5 min	4 wks					start vs warm-up
15	AHU-2	econo damper %	BAS	OAD	5 min	4 wks					
14	AHU-1	supply flow	BAS	SA-F	1 sec	60 min					15 Hz/min test rate
15	AHU-5	MAT filter face 1	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
11	AHU-1	hallway temp	BAS	ZN-T	5 min	4 wks					start vs warm-up
8	AHU-5	160E min OA SP	BAS	160E min OA SP	5 min	4 wks		4 wks later			sensor checks
8	AHU-5	160C zone CO2	BAS	160C zone CO2	5 min	4 wks		4 wks later			sensor checks
13	AHU-3	final filter p drop	BAS	FF-P	1 sec	60 min					15 Hz/min test rate
15	AHU-3	econo damper %	BAS	OAD	5 min	4 wks					
12	AHU-5	Preheat discharge	Temp Logger		1 min	4 wks					sensor/simult issues?
13	AHU-5	final filter p drop	BAS	FF-P	1 sec	60 min					15 Hz/min test rate
+	Elec	bldg kW or kWh	BAS	ELEC-MTR	15 min	4 wks					to track performance
8	AHU-5	econo min OA SP	BAS	econo min OA	5 min	4 wks		4 wks later			verify min OA reset
11	AHU-5	AHU start time	BAS	SF-S	COV	4 wks					start vs warm-up
24	Cisterns	613 tank pump	Amp Logger		1 min	4 wks		2 wks			4-channel + 20 amp CT
12	AHU-5	Cooling discharge	BAS	SA-T	15 min	4 wks					sensor/simult issues?
15	AHU-5	MAT filter face 8	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
3	AHU-3	critical VAV box	BAS	avg damper %	15 min	4 wks					to track DSPR
17	HWS	boiler status	Amp Logger		5 sec	4 dys					4-channel + 20 amp CT
+	NG	bldg therms	BAS	GAS-MTR	15 min	4 wks					to track performance
15	AHU-1	econo temps	BAS	OAT	5 min	4 wks					also graph all OATs
14	AHU-3	supply flow	BAS	SA-F	1 sec	60 min					15 Hz/min test rate
18	HWS	spare well HWRT	Temp Logger		5 min	4 wks					4-channel + temp probe
16	ChWS	chiller status	BAS	chiller status or S/S	COV	4 wks					RA/OA from ECM 14

Monitoring Plan

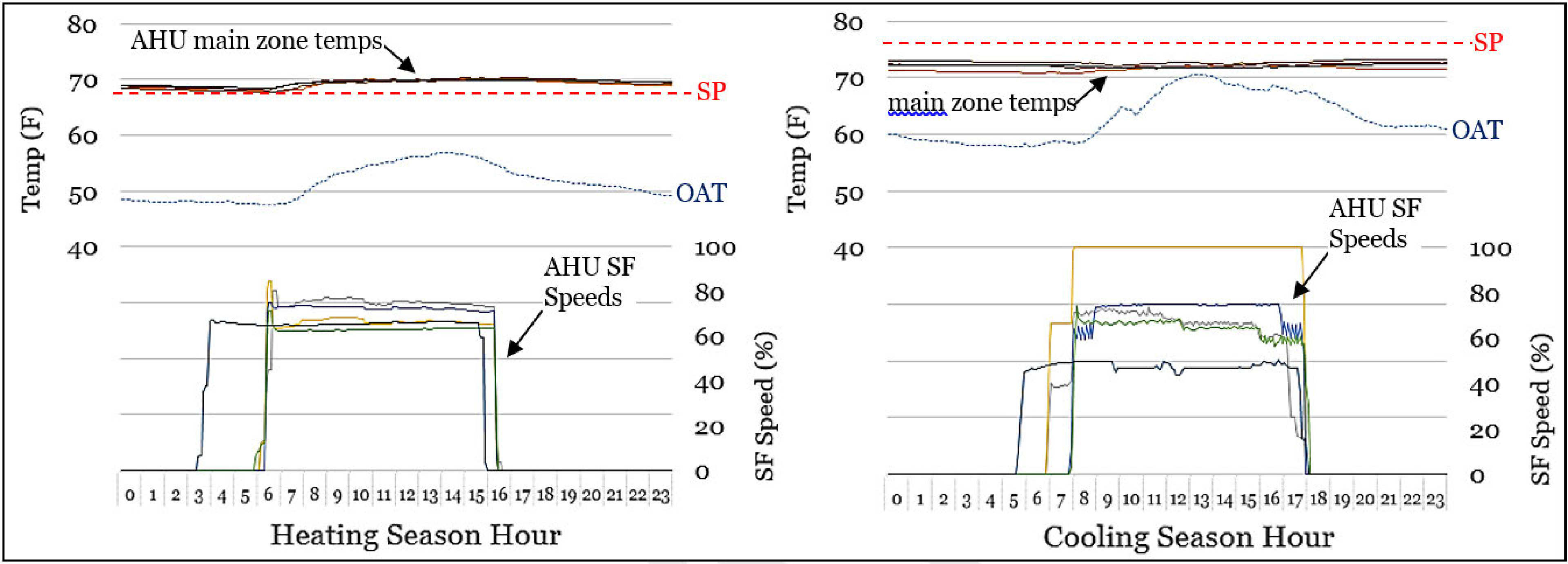
ECM	System	Location	Type	Point Name or Logger ID	Trend Interval	Trend Legnth	Dates			Status	Notes
							Launch	Download 1	Download 2		
15	AHU-3	econo temps	BAS	RAT	5 min	4 wks					
15	AHU-5	MAT filter face 2	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
7	AHU-5	160B zone temp	BAS	160B zone temp	5 min	4 wks		4 wks later			to check averaging
8	AHU-5	160A zone CO2	BAS	160A zone CO2	5 min	4 wks		4 wks later			sensor checks
15	AHU-5	MAT filter face 6	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
25	Cisterns	vending mach 1	Plug Logger		1 min	2 wks					WattsUp tool
3	AHU-2	critical VAV box	BAS	max damper %	15 min	4 wks					to track DSPR
22	Ex Ltg	Bathroom 3	Occ/lt Logger		COV	2 wks					
7	AHU-5	160B temp SP	BAS	160B temp SP	5 min	4 wks		4 wks later			to check averaging
8	AHU-5	160? zone CO2	CO2 Logger		5 min	4 wks					sensor checks
17	HWS	mech HW supply	Flow Meter		5 min	4 wks					Ultrasonic flowmeter
10	AHU-2	AHU SF flow	BAS	SF-F	5 min	4 wks					do AHU's VAV?
8	AHU-5	160A min OA SP	BAS	160A min OA SP	5 min	4 wks		4 wks later			sensor checks
17	HWS	pressure switch	BAS	HW-P	COV	4 wks					check for low flow trips
15	AHU-3	MAT filter face 4	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
3	AHU-1	critical VAV box	BAS	max damper %	15 min	4 wks					to track DSPR
6	HWS	HWP motor status	Status Logger		COV	1 wk					check HWP runtime
12	AHU-5	Cooling discharge	Temp Logger		1 min	4 wks					sensor/simult issues?
11	AHU-5	auditorium temp	BAS	ZN-T	5 min	4 wks					start vs warm-up
22	Ex Ltg	Bathroom 1	Occ/lt Logger		COV	2 wks					
7	AHU-5	160G zone temp	BAS	160G zone temp	5 min	4 wks		4 wks later			to check averaging
15	AHU-2	econo temps	BAS	OAT	5 min	4 wks					also graph all OATs
15	AHU-3	MAT filter face 6	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
14	AHU-4	supply flow	BAS	SA-F	1 sec	60 min					15 Hz/min test rate
15	AHU-1	econo damper %	BAS	OAD	5 min	4 wks					
13	AHU-1	final filter p drop	BAS	FF-P	1 sec	60 min					15 Hz/min test rate
12	AHU-5	Cooling discharge	Temp Logger		1 min	4 wks					sensor/simult issues?
15	AHU-5	OAT	Temp Logger		15 sec	1.5 wk					
15	AHU-5	MAT filter face 4	Temp Logger		15 sec	1.5 wk					4-channel + temp probe
12	AHU-5	Preheat discharge	Temp Logger		1 min	4 wks					sensor/simult issues?
8	AHU-5	160? Occ/light	Occ/lt Logger		COV	4 wks		4 wks later			meas auditorium occ
3	AHU-5	critical VAV box	BAS	max damper %	15 min	4 wks					to track DSPR

Auditorium CO2 vs AHU SF Speed
Performance Trend

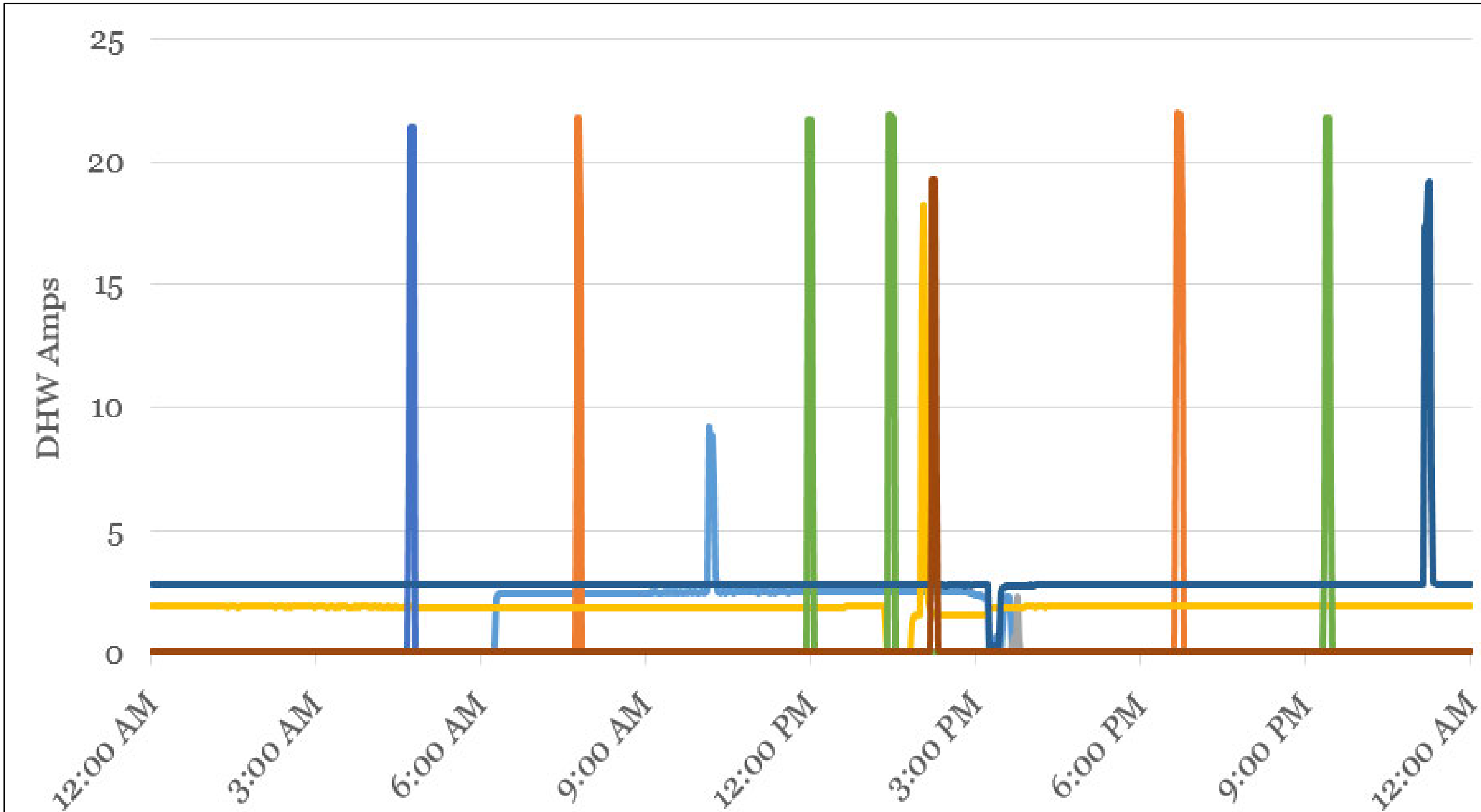


Heating and Cooling Season: Typical Zone Temps and AHU SF Speeds

Performance Trend

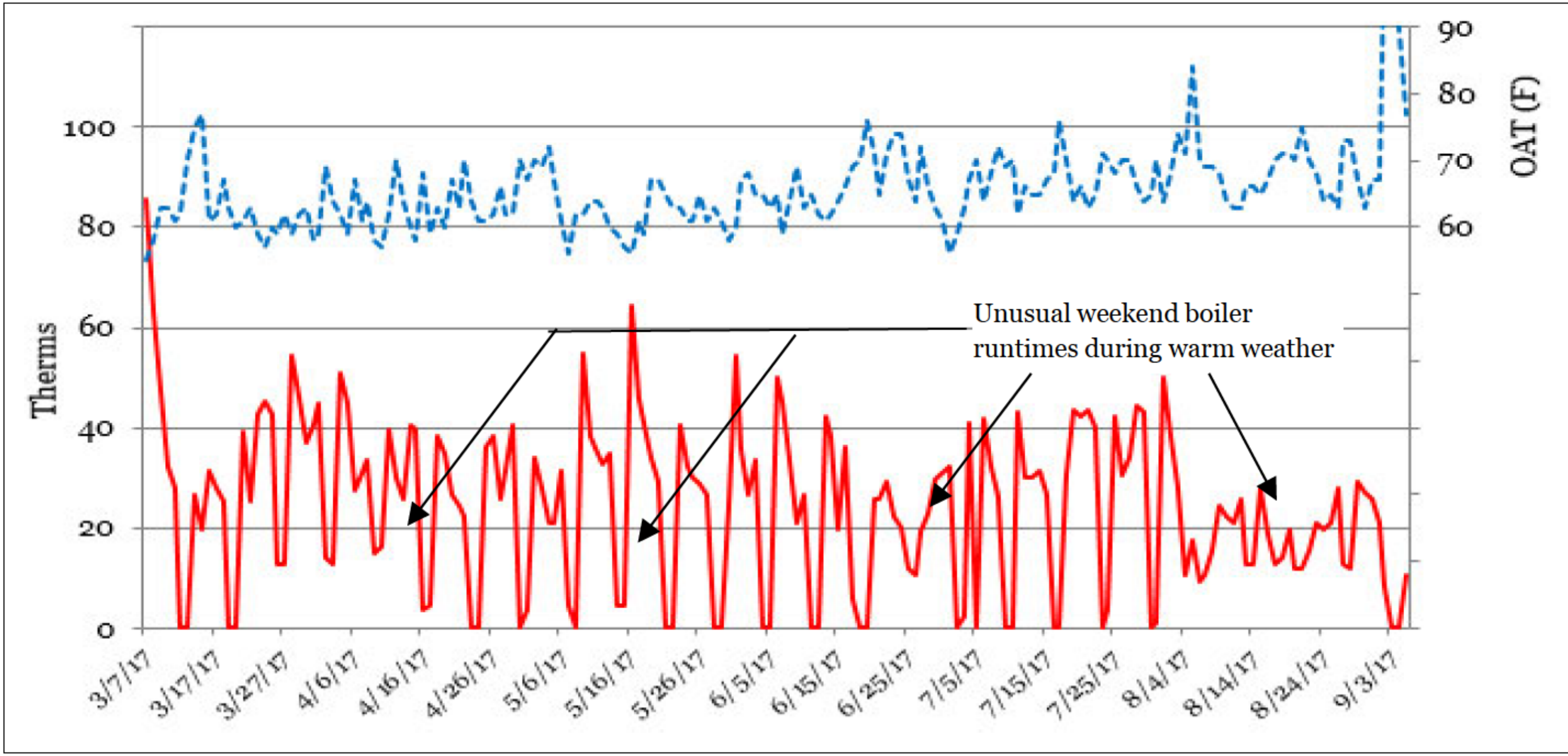


1-Day DHW Heater Amps
Performance Trend



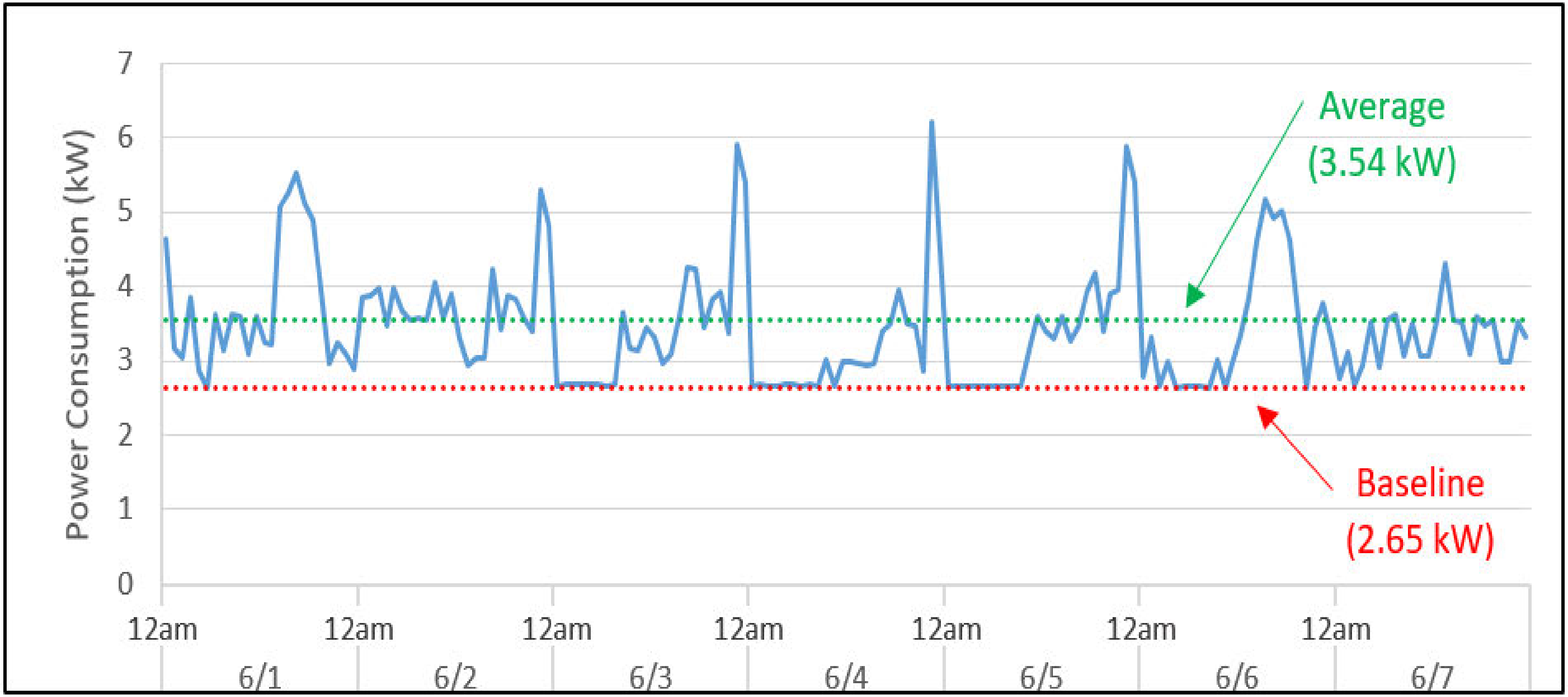
BAS Boiler Therms – ½ Year Trend

Performance Trend



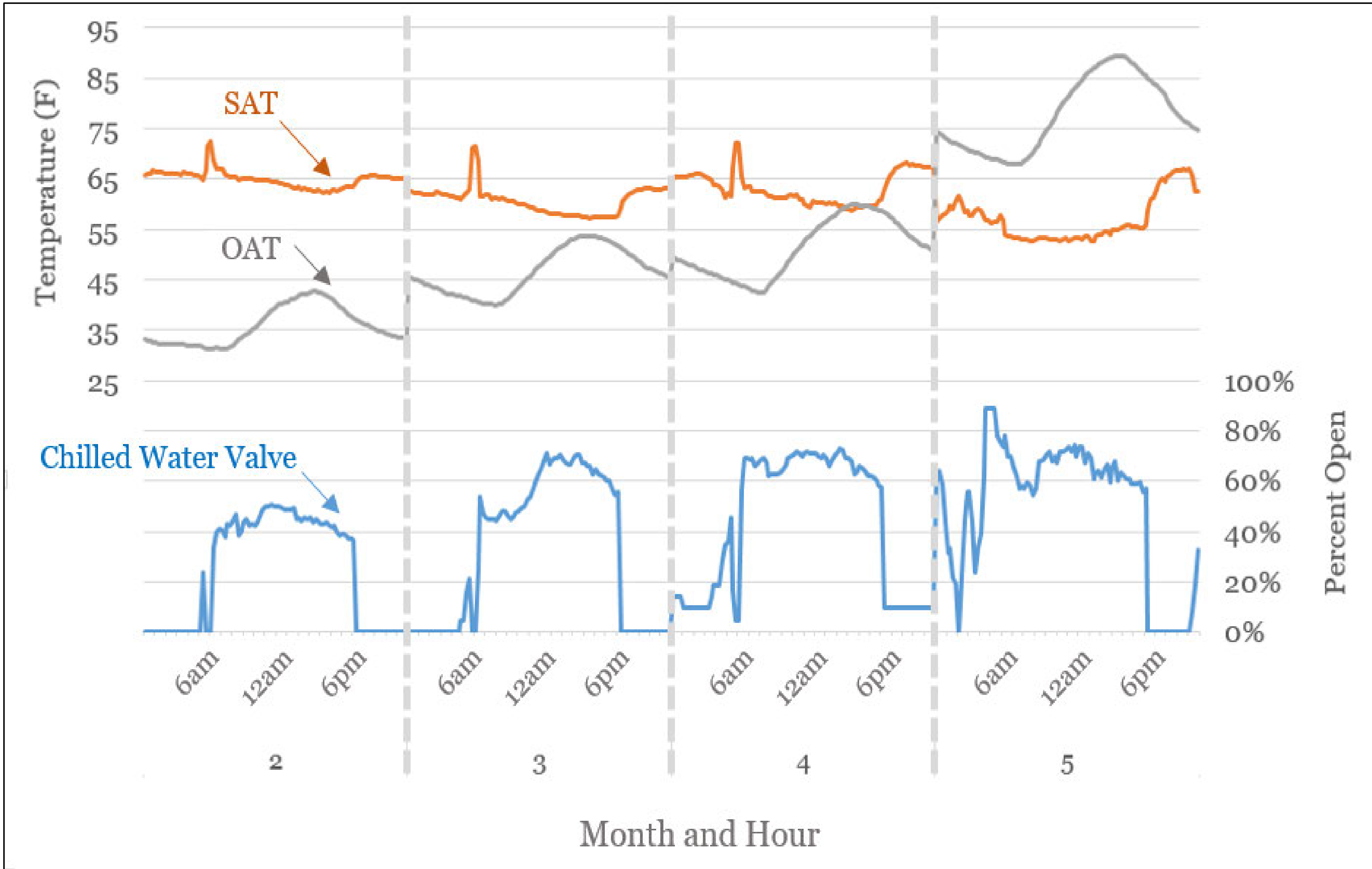
CRAC Unit Dent Data

Performance Trend



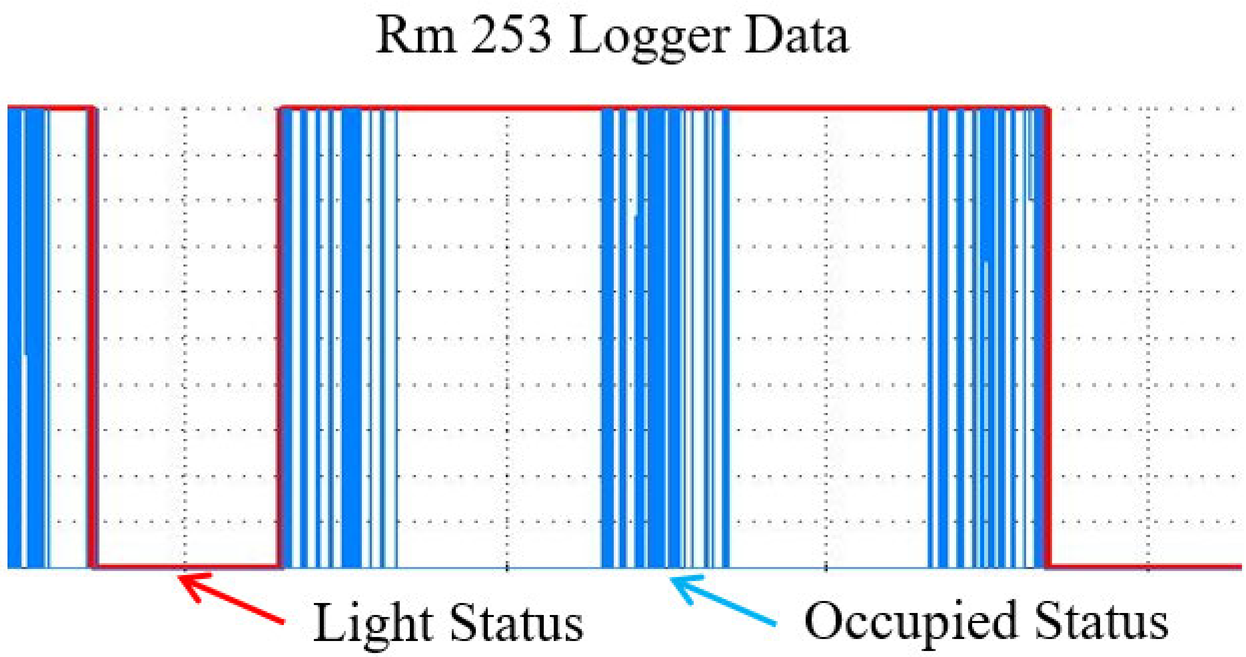
Average SAT, OAT, and AHU ChW Valve Positions

Performance Trend

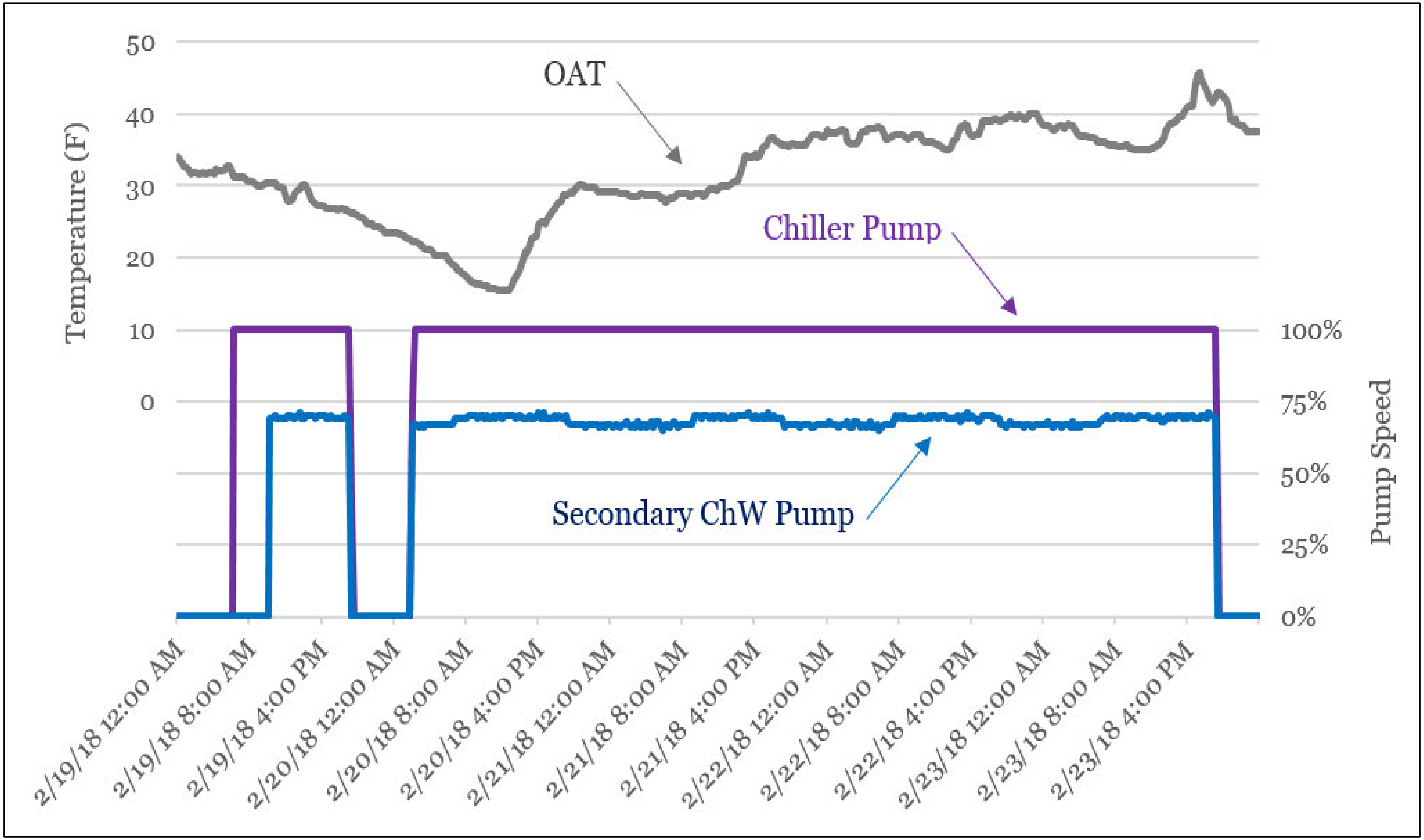


Light Status vs Occupancy Data

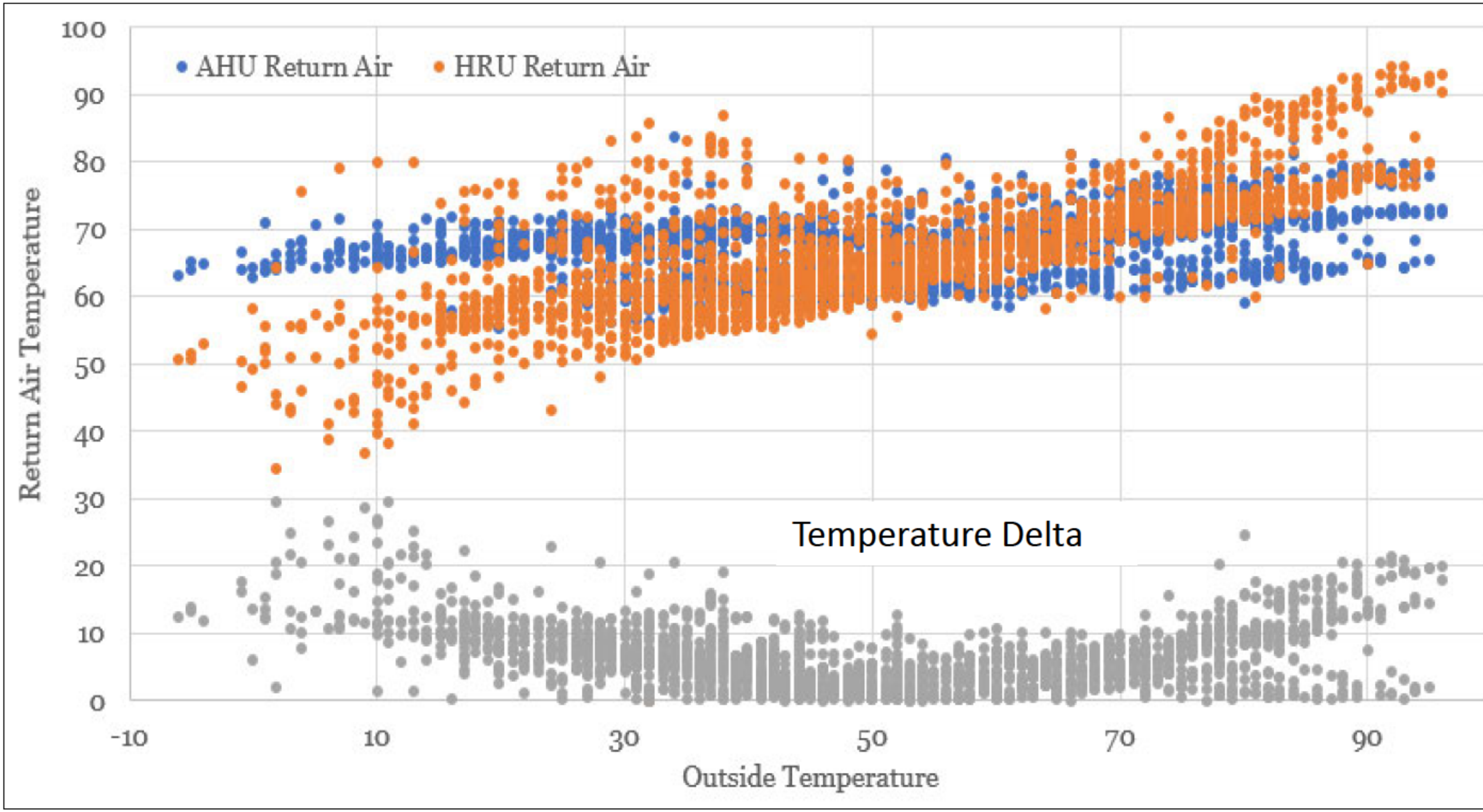
Performance Trend



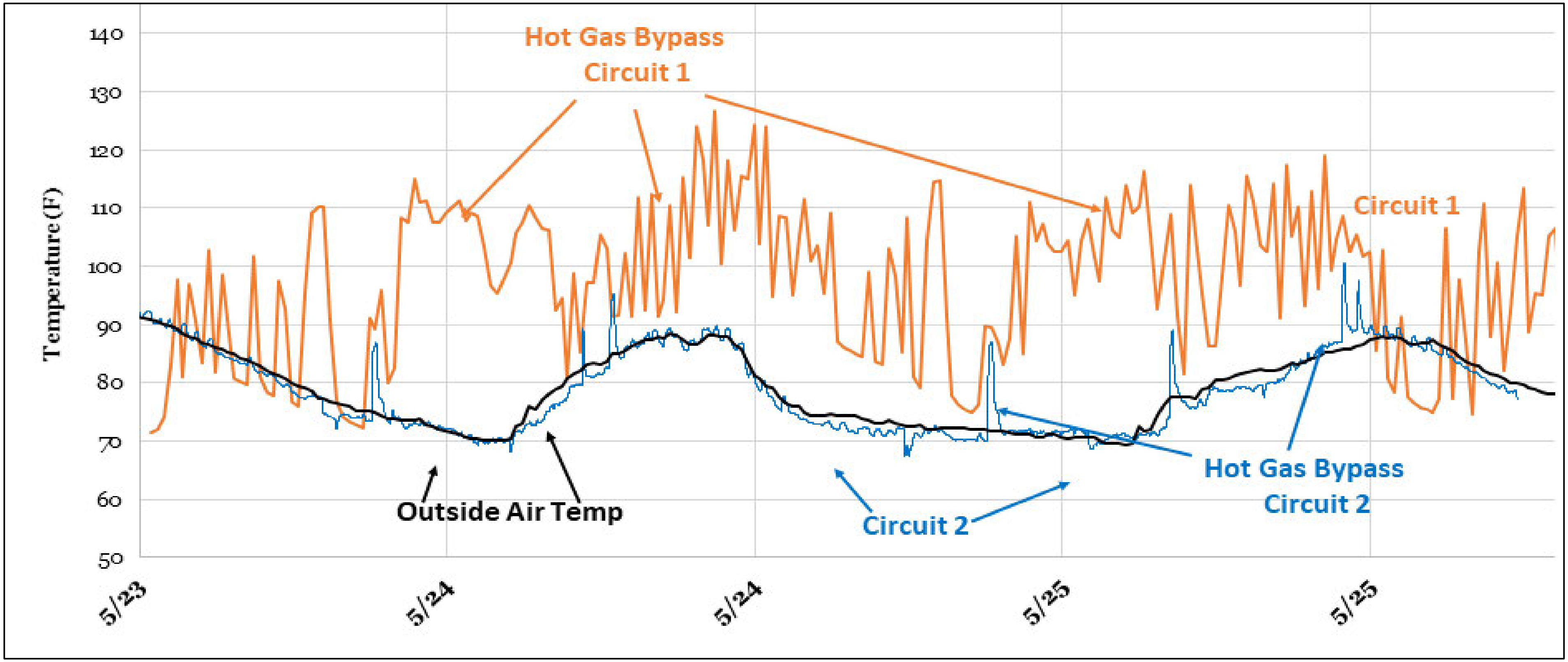
Equipment Enables
Performance Trend



DOAU Heat Recovery
Performance Trend

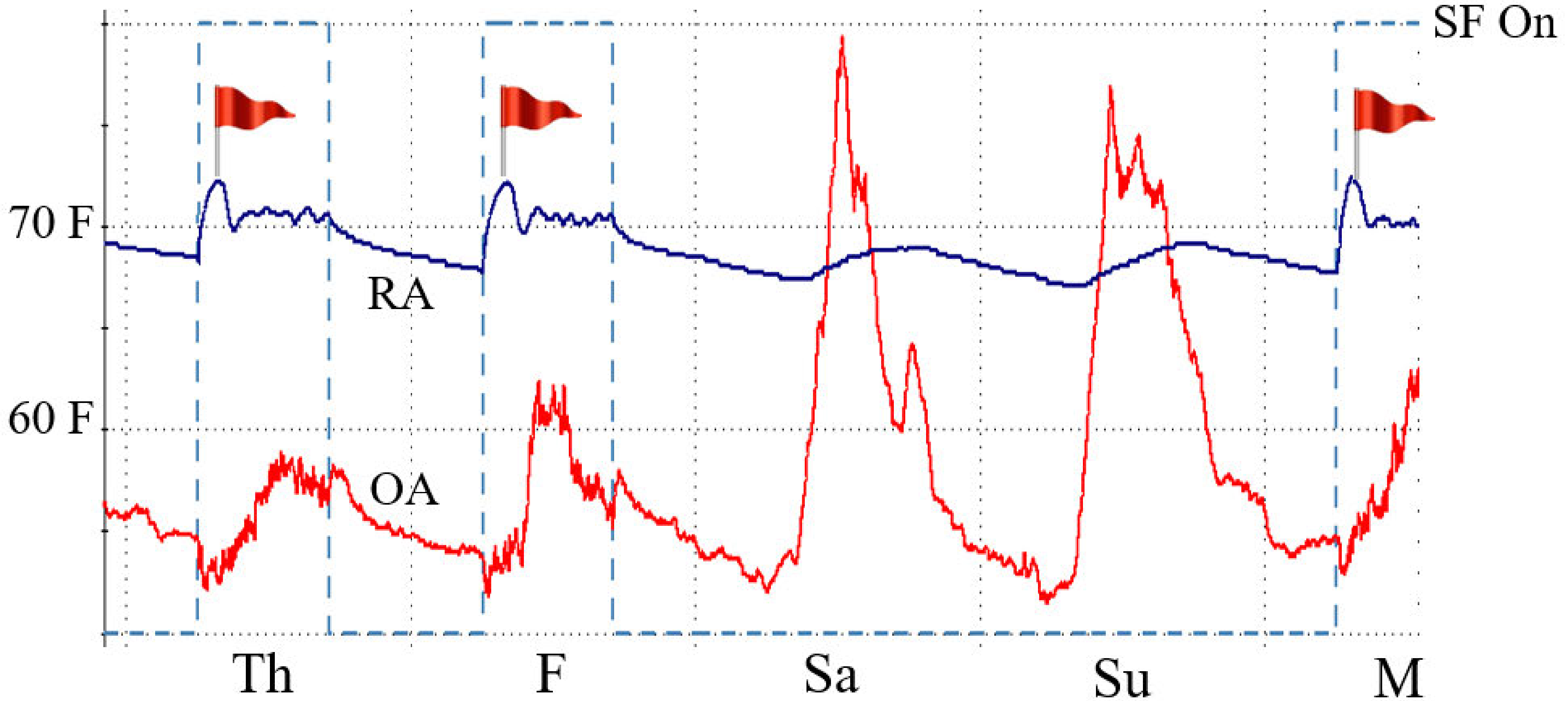


Chiller Hot Gas Bypass Use
Performance Trend



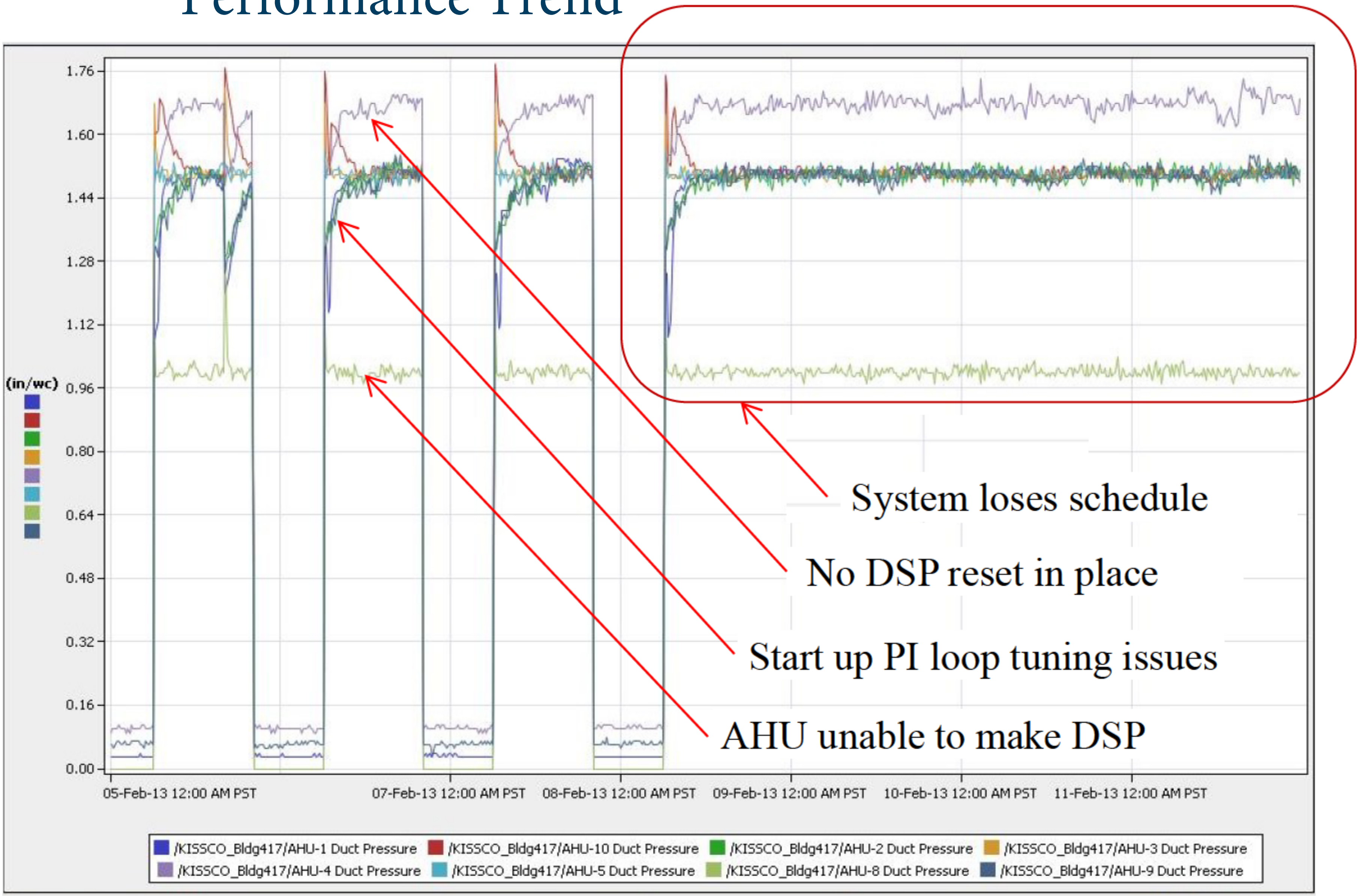
1-Week AHU Warm-up Optimization Study

Performance Trend

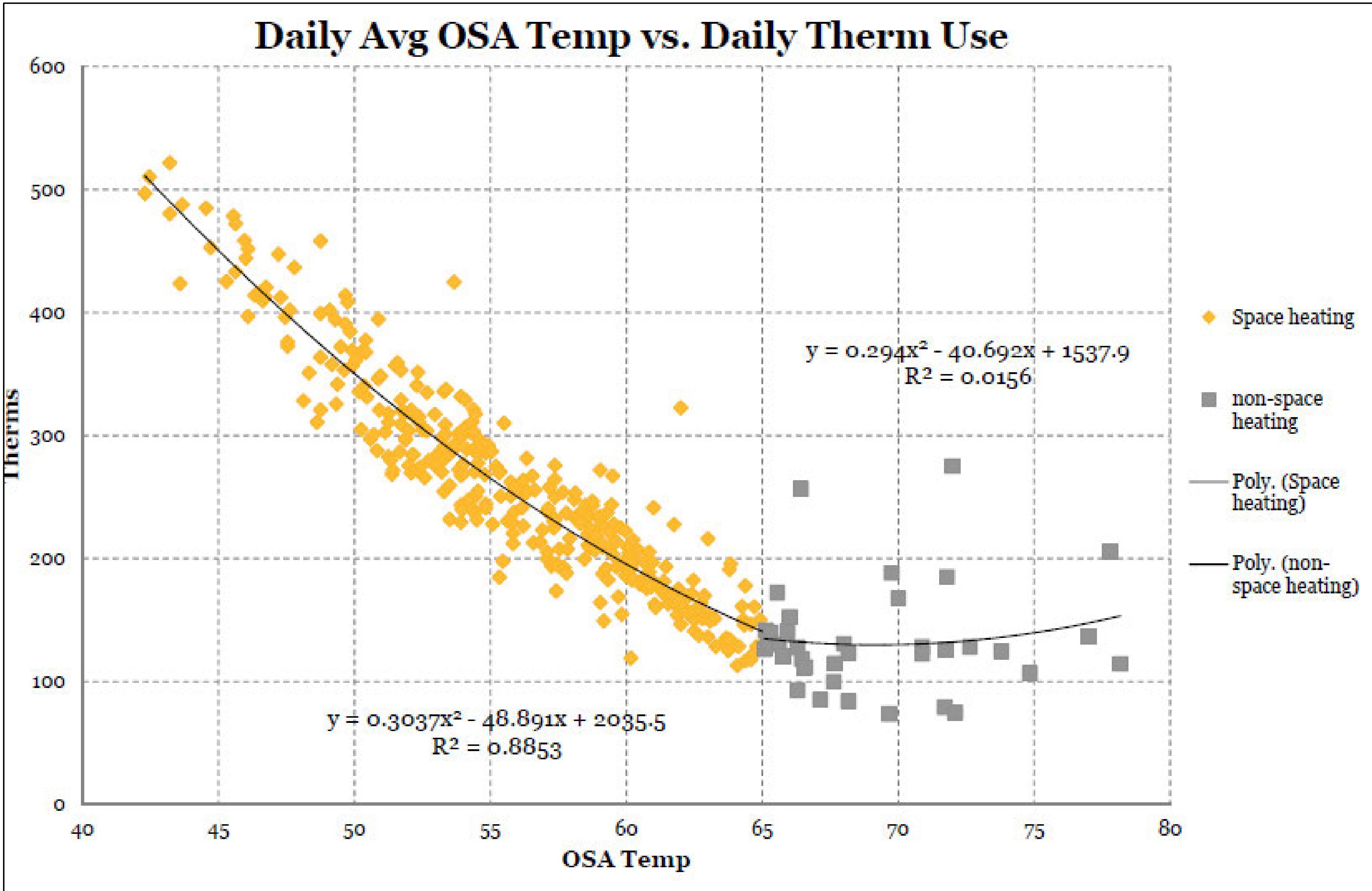


BAS AHU Duct Static Pressure Readings

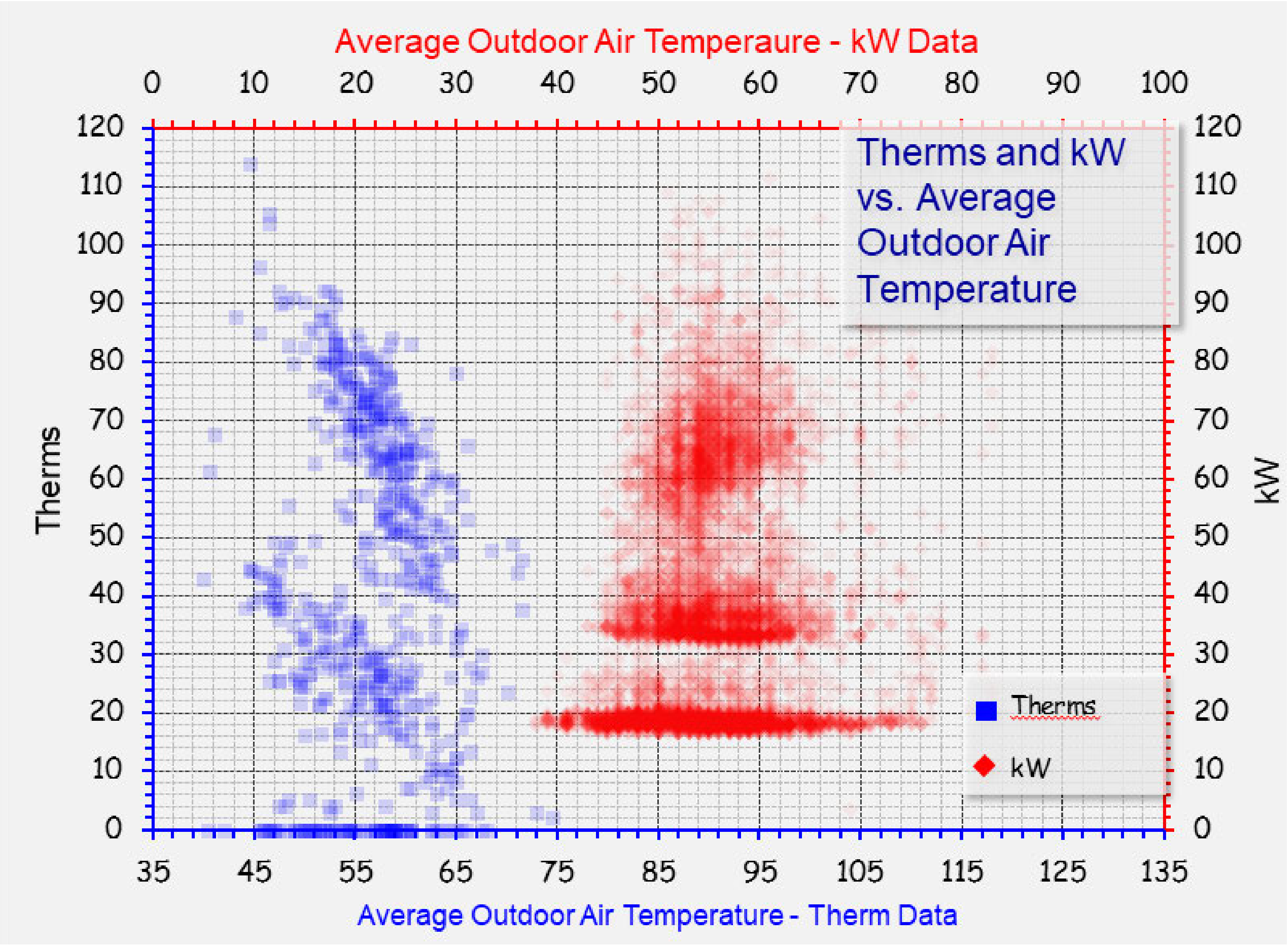
Performance Trend



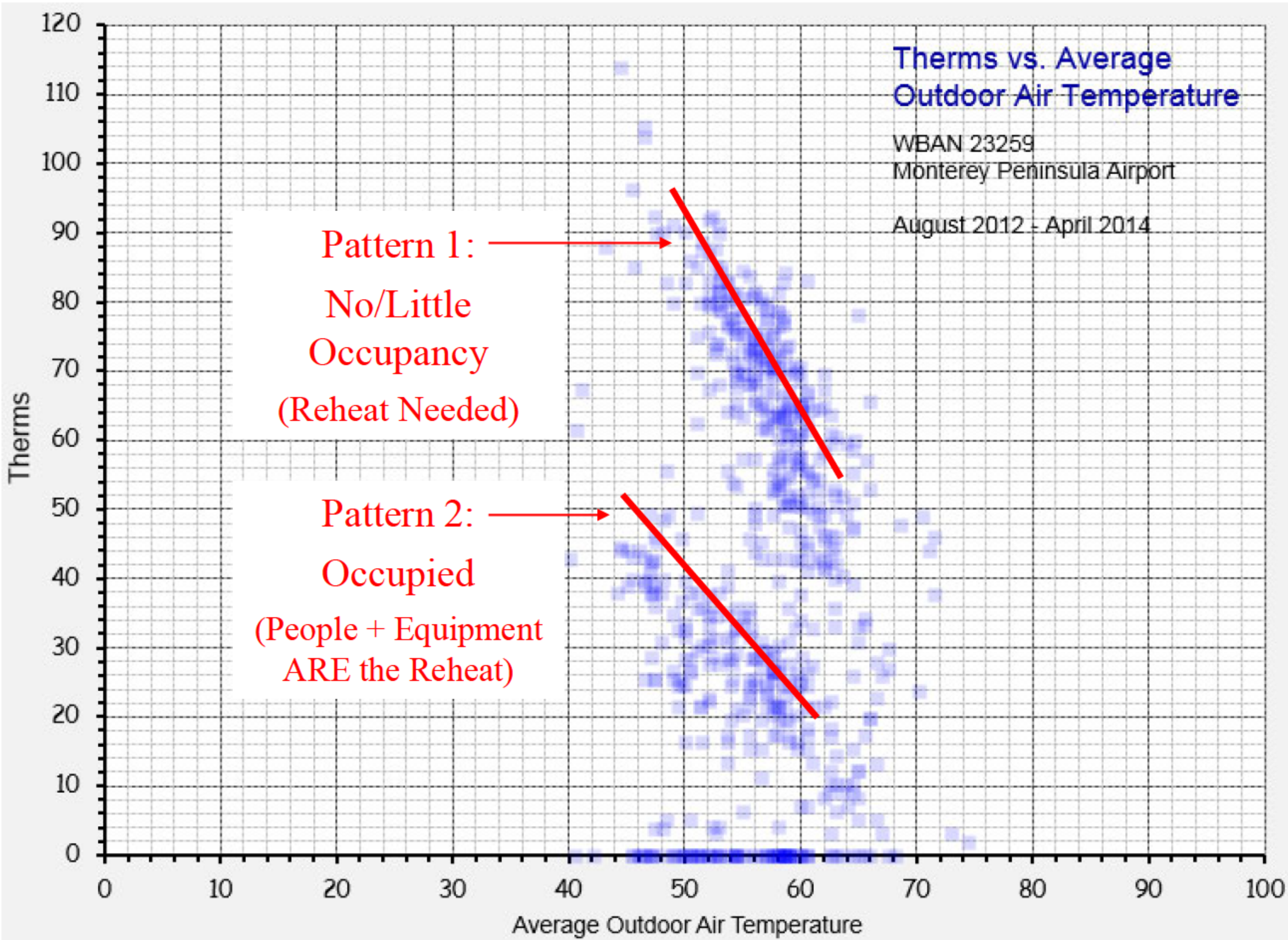
Scatter Plot Performance Data Trend



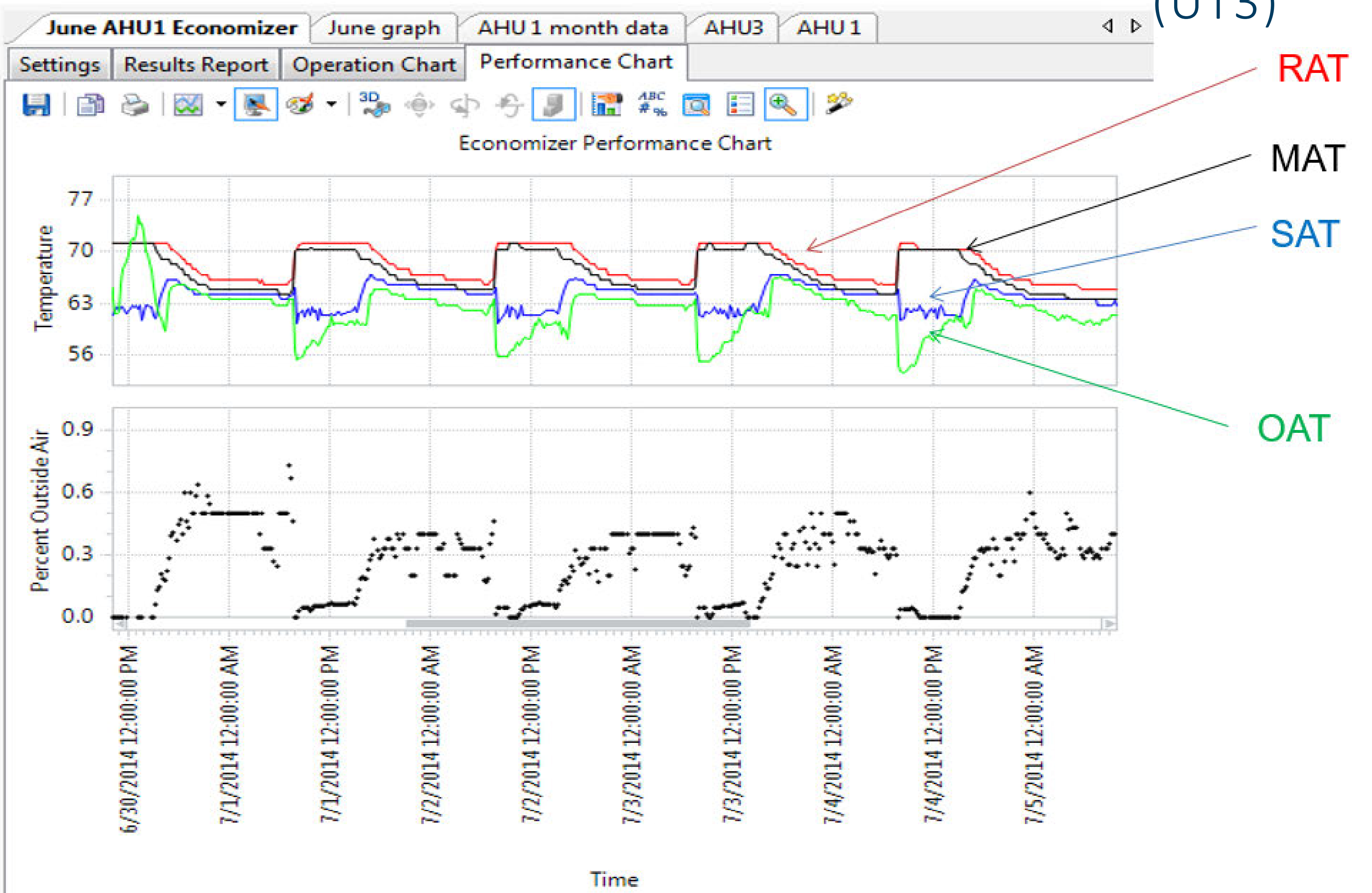
Scatter Plot Performance Data Trend



Scatter Plot Performance Data Trend

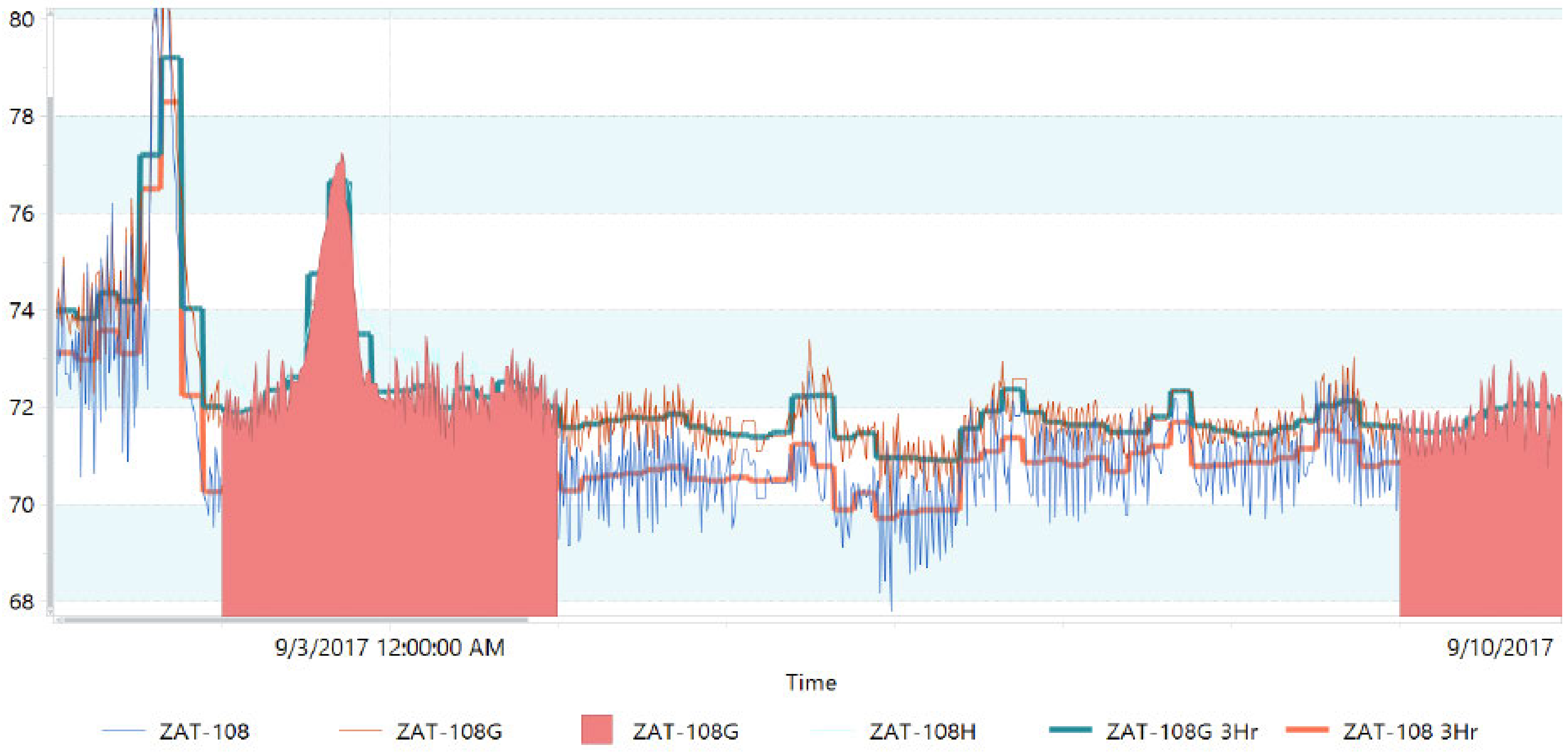


UT3 Air-side Economizer Analysis Trend (UT3)



UT3 Averaging and Envelope Functions

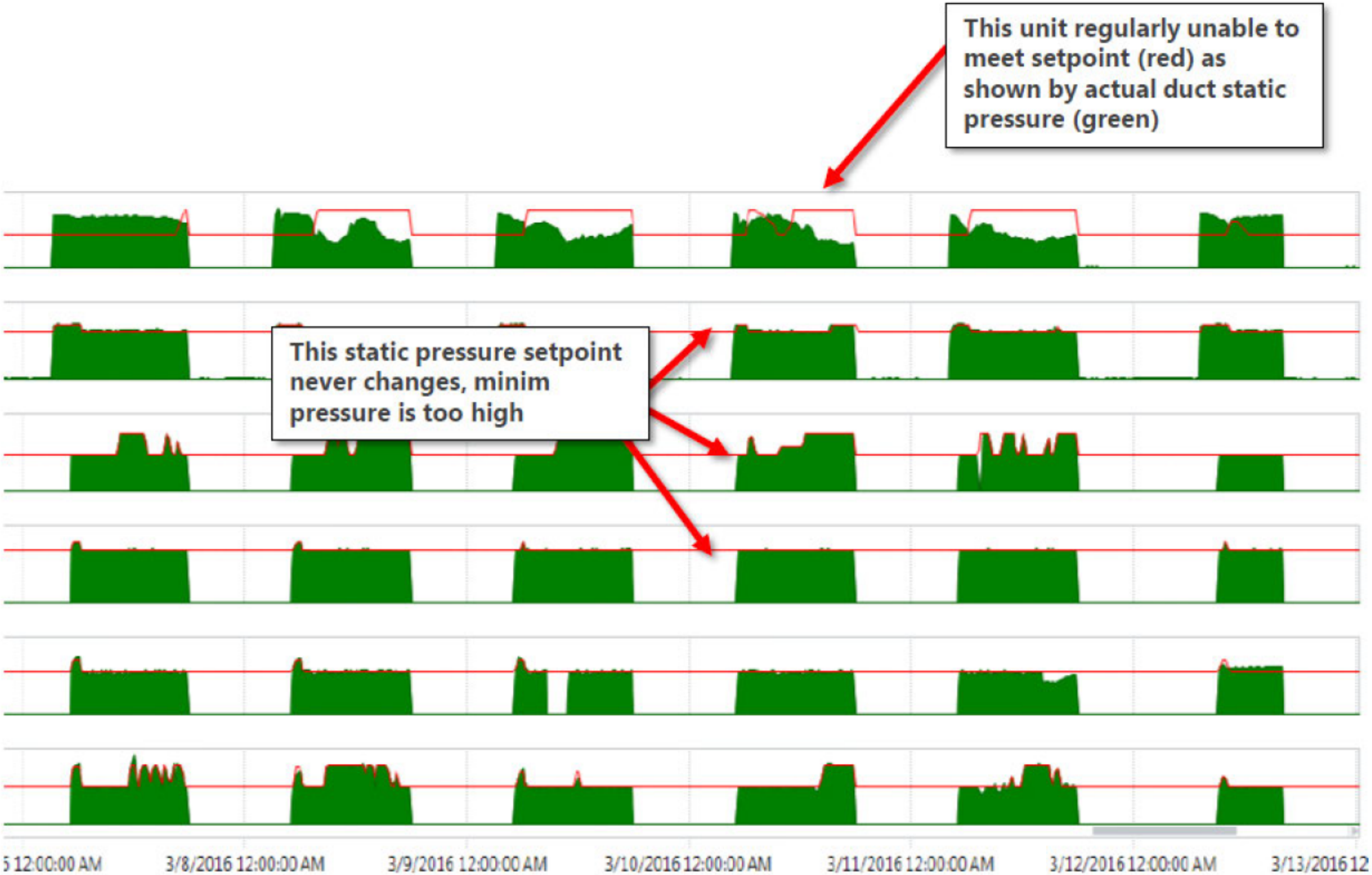
Performance Trend



Courtesy: Reinhard Seidl, Taylor Engineering

UT3 Template Groups

Performance Trend

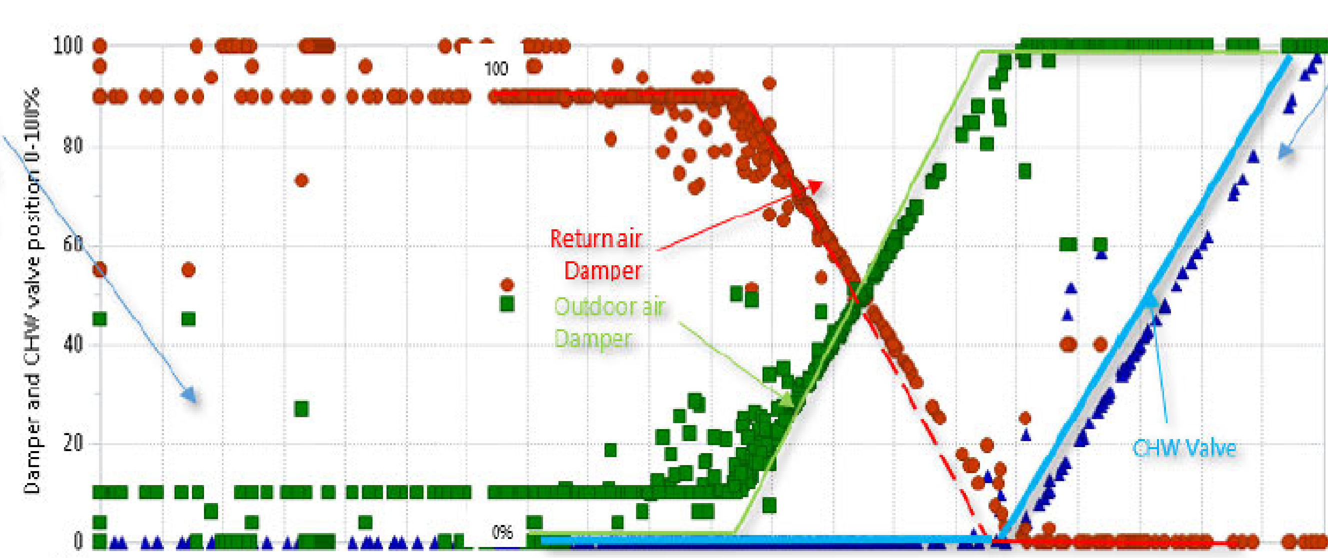


Courtesy: Reinhard Seidl, Taylor Engineering

UT3 Scatter Charts

Economizer Performance Trend

10% minimum on OA damper per RSA TAB Report, so correct.



OA and RA damper operation ok, CHW valve ok

Courtesy: Reinhard Seidl, Taylor Engineering

Pump Test Form

Building: Central plant

System: Hot water system

Component or Function to be tested: HWP-X

Purpose: Briefly describe the purpose of the test to be performed.

RCx team suspects secondary hot water pumps for the building to be oversized due the substantially closed position of the discharge triple duty valve (TDV), the purpose of this test is to validate impeller size, measure current and full-open pump flows (in GPM), and determine impeller trim size.

Instructions: Provide instructions regarding how the test results should be documented and what (if any) follow up actions are necessary.

Record test measurements and impeller trim conditions in this form and on the pump curve. Follow up with energy savings associated with impeller trim, cost estimate, and ROI information.

Equipment Required: Note any special test equipment requirements.

Charged, calibrated hydromanometer (with B&G fittings), crescent wrench, and 6 foot ladder to reach TDV stem

Acceptance Criteria: Document the acceptance criteria that will indicate that the test was passed.

Test complete when the test procedure information has been gathered, system has been returned to normal, and an impeller trim opportunity has been successfully plotted on the pump curve.

Precautions: Document any precautions that need to be taken before, during, or subsequent to the test.

Hot water supply temperature setpoint of 180F can cause burns as it leaks out of TDV ports, reduce hydronic temperatures for test duration. Do not force hydromanometer probes into TDV ports for risk of damaging test port seals. Do not deadheand for more than 5 minutes. Practice ladder safety. If any unexpected conditions arise during test (major leaks, pump malfunction, controls issues, etc), abort test and notify POCs.

References: List references like technical papers, CTPL library tests and other information that might be useful as supporting information for the test team.

Bring printouts of TDV and pump performance curves: (list model information); reference affinity laws

Roles and Responsibilities: List the required participants, and their roles and responsibilities.

1. RCx lead: performs test
2. RCx test support: documents measurements and aides in test completion
3. HVAC programmer: reduces (or advises on) setpoint reduction and temporary overrides
4. HVAC technician: on-call to support any test problems or repair needed
5. O&M Chief/Foreman: awareness and prior approval of test date

Functional Test

Requirement	Data	Initials
Prerequisites: List any prerequisites that must be in place		

1. Hydronic temperature must be < 150F
2. Two-way zone valves must be mostly open so that average valve position > 85%
3. Above roles & responsibilities must be in place
4. Equipment and references must be available
5. At least one hour must be available to perform/re-perform this test

Preparation: List steps necessary to prepare for the test.

1. Setup hydromanometer with correct fittings and hose valves closed
2. Connect the positive hydromanometer probe to the upstream TDV port
3. Turn the hydromanometer on and selector switch to BYPASS
4. Point the negative hydromanometer probe towards a floor drain or bucket and open both hose valves
5. Bleed lines until smooth stream is present, then close both hose valves
6. Connect the negative probe to the downstream TDV port
7. Turn the hydromanometer on and selector switch to MEASURE

Procedure

Requirement	Data	Initials
1. Note current TDV position	80 % open	BC
2. Note current TDY hydromanometer differential pressure	4.5 ft head	BC
3. Is the differential pressure above TDV manufacturer read minimum?	yes/~~no~~	BC
4. Deadhead pump by adjusting TDV stem to 0% open	0% open	BC
5. Note deadhead hydromanometer differential pressure	~~___ ft head~~	BC
6. Adjust TDV stem to 100% open	100% open	BC
7. Note full open hydromanometer differential pressure	3.5 ft head	BC
8. Is the differential pressure above TDV manufacturer read minimum?	yes/~~no~~	BC

Follow up and Return to Normal:

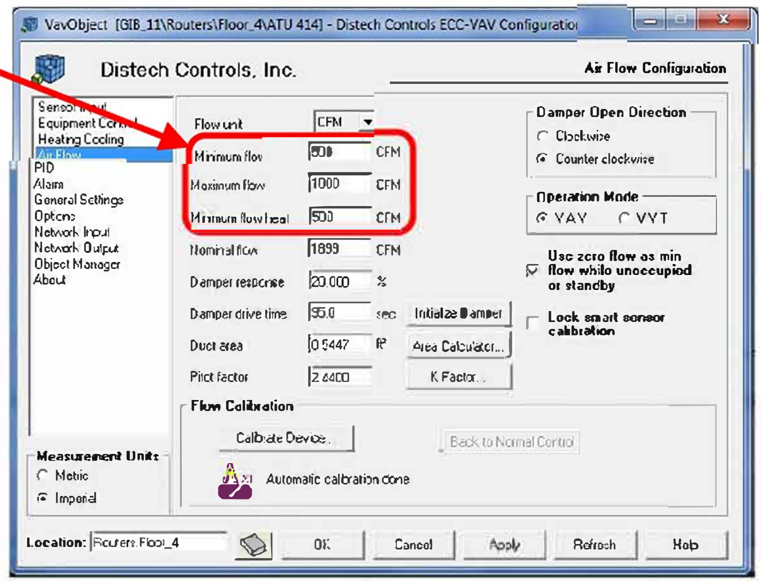
Requirement	Data	Initials
1. Return the TDV stem to original position	80% open	BC
2. Remove any hot water system overrides	yes/~~no~~	BC
3. Verify system returns to normal operation (boiler on, setpoint met) ---	yes/~~no~~	BC
4. Plot flow conditions on TDV performance curve	yes/~~no~~	BC
5. Plot flow conditions on pump performance curve	yes/~~no~~	BC
6. Note current impeller size	9.25 " diam	BC
7. Note current flow condition	440 gpm	BC
8. Note full open flow condition	550 gpm	BC
9. Plot full open system curve using affinity laws	yes/~~no~~	BC
10. Note impeller trim size	7.375 " diam	BC
11. Note current BHP	9.5 BHP	BC
12. Note impeller trim BHP	5.5 BHP	BC

1.1.1 Ventilation Airflow Setpoint Adjustments

Recommended Execution: BAS Programmer/TAB Targeted Systems: AHU 1-4
Calculated Savings: $6,090/yr (218,000 kBtu/yr) Cost Estimate: $3,600 (< 1 yr SPB)

Equipment controllers are capable of setting dual flow minimums (heating vs ventilation)

Figure 1 Building 613 VAV box airflow configuration features



ECM Description:

The overventilation clues are there: baseline gas usage is high, AHU fans and zone boxes show little flow variation, and O&M reports higher instances of cold complaints. On average zones appears nearly 25% vacant and a zone-by-zone ASHRAE Ventilation Rate Procedure (VRP) analysis reveals that VAV minimum flows in total were designed and configured over three times what was required despite VAV box controllers readily capable of configuring dual minimum setpoints.

See Appendix for recalculation of each zone CFM's minimum CFM setpoint. Provide this table to the BAS programmer for 1 day of box reconfiguration and testing. Though AHU minimum design flows closely correspond to ASHRAE VRP values, we recommend concurrently scheduling a TAB contractor for AHU 1-4 rebalance due to the recently rebuilt economizer linkage assemblies and faulty AHU pressure readings found during functional testing. This ECM represents a major energy driver and even conservative savings estimates justify this additive TAB work at near immediate payback.

Calculations:

Reduced fan power and decreased ventilation loads provide energy savings using recalculated ASHRAE VRP figures, part-load fan pressures, and bin hours for facility operation linked to minimum flow modes. A 70% safety factor has been included since perimeter space heating needs and the aggressive chiller lockout may affect savings as calculated. The existing minimum fan speeds may also limit savings, however we recommend reducing both BAS and VFD minimum setpoints from 25% to 20% based on manufacturer data to better balance low-load operation with motor efficiency trends.

Annual Fan Savings:

$$\frac{33{,}855 \text{ CFM} \times 3.0''}{6{,}356 \times 0.49} \times 0.746 \times 1{,}180 \text{ hrs} \times 0.70 = 20{,}260 \text{ kWh} = \$4{,}460$$

Annual Ventilation Load Savings:

$$\frac{1.08 \times 8{,}465 \text{ CFM} \times (69F - 55F)}{100{,}000 \times 0.71} \times 1{,}180 \text{ hrs} \times 0.70 = 1{,}490 \text{ th} = \$1{,}630$$

1.1.2 Auditorium Demand-Controlled Ventilation (DCV)

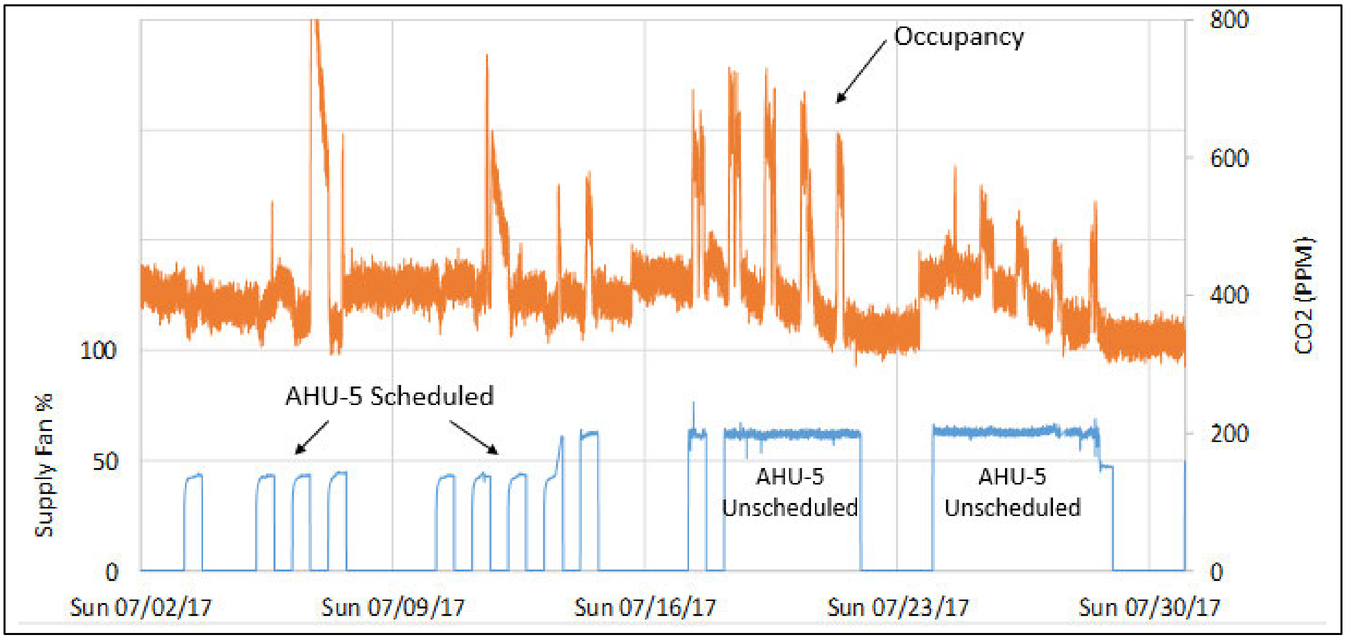
Recommended Execution: BAS Programmer

Targeted Systems: AHU 5

Calculated Savings: $2,430/yr (175,500 kBtu/yr)

Cost Estimate: $600 (< 1 yr SPB)

Figure 2 AHU 5 supply fan status and zone CO2 logger readings for a sample month



ECM Description:

Despite serving sporadically occupied auditorium spaces, AHU 5 is currently scheduled with the rest of the building. We recommend adjusting the AHU 5 field controller schedule for an optimized morning warm-up period only (economizer dampers closed), 4-hour enables from any thermostat override or low temperature, standby temperatures at 62.5F, and occupant coordination including signage (see Appendix for recommended thermostat labels).

Configure any zone override to open both quadrant boxes. Ensure zone boxes are configured to close when unoccupied. Functional testing shows thermostat overrides are operational and AHU 5 does not trip on high discharge pressure with only two boxes open. Estimated time for reconfigurations and testing is 4 hours.

Calculations:

Supply and return fan savings and eliminated ventilation loads are calculated for when AHU 5 can be left off after warm-up with no enable override or low-temperature. Pump savings associated with reducing hot water flows to zone reheat coils are negligible. Savings estimates are considered conservative, however, as no partially occupied or cooling loads are calculated and accidental unscheduled AHU 5 operations are not counted.

Annual Fan Savings:

$$\frac{5{,}320 \text{ CFM x } 1.7''}{6{,}356 \text{ x } 0.49} \text{ x } 0.746 \text{ x } 1{,}275 \text{ hrs} = 2{,}780 \text{ kWh} = \$610$$

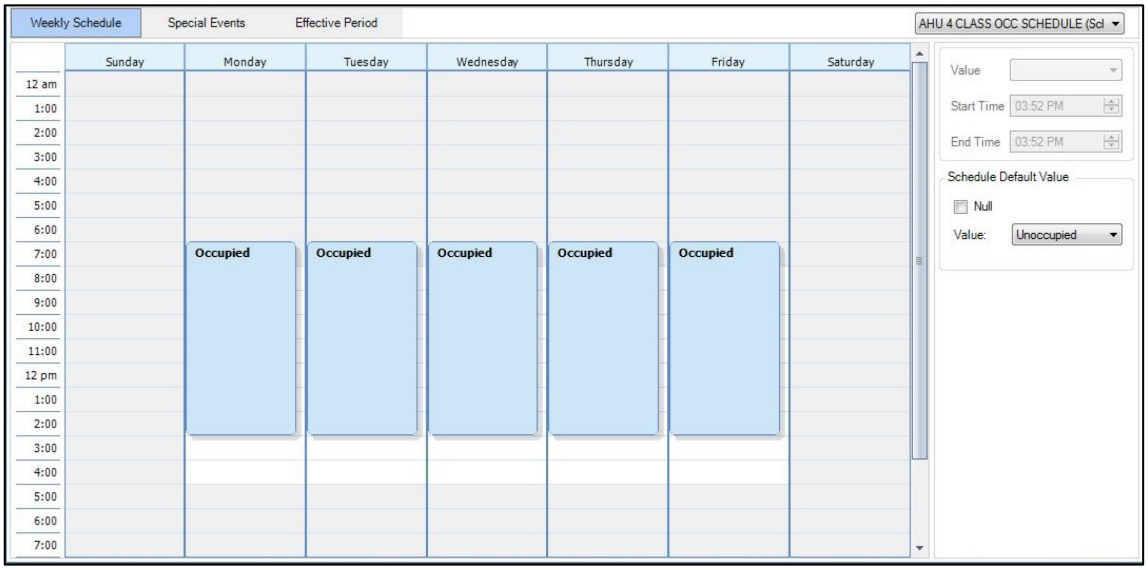
Annual Ventilation Load Savings:

$$\frac{1.08 \text{ x } 5{,}320 \text{ CFM x } (72\text{F} - 56\text{F})}{100{,}000 \text{ x } 0.71} \text{ x } 1{,}275 \text{ hrs} = 1{,}660 \text{ th} = \$1{,}820$$

1.1.3 Zone-Level Classroom Scheduling

Recommended Execution: BAS Programmer | Targeted Systems: AHU 1-4
Calculated Savings: \$2,200/yr (123,000 kBtu/yr) | Cost Estimate: \$600 (< 1 yr SPB)

Figure 3 Each AHU controller supports configuration of a shortened schedule for classroom VAV boxes



ECM Description:

Instructional spaces regularly go unoccupied at the end of the school day, then continue to ventilate and condition empty rooms for the remaining 2 hours until the building schedule disables AHUs 1-4. Rather than sending a single occupied schedule to every VAV on a given floor, each AHU controller can be setup with secondary schedules tailored to the shortened classroom day.

Separated zone schedules, 2-hour override functionality, and box closures during unoccupied modes have all been accomplished during the RCx Investigation Phase. Only final reconfiguration of AHU controllers and coordination with occupants is needed to begin realizing savings. Class and office space thermostat labels are also included in the Appendix.

Calculations:

Zone scheduling is yet another solution for the prevention of energy systems supporting vacant spaces. The savings are thus additional sets of calculations for the reduction in fan power and ventilation loads. The updated minimum VAV box flow setpoints from the previous ECM are applied here, however it is less likely that occupied boxes will be at minimum in the hours of 3pm-5pm meaning that AHU fans should have additional turndown capacity. Nevertheless, a safety factor of 85% is applied to account for infrequent occurrences of students or staff requesting HVAC in classroom spaces after 3pm.

Annual Fan Savings:

$$\frac{15{,}200 \text{ CFM} \times 3.0''}{6{,}356 \times 0.49} \times 0.746 \times 500 \text{ hrs} \times 0.85 = 4{,}690 \text{ kWh} = \$1{,}030$$

Annual Ventilation Load Savings:

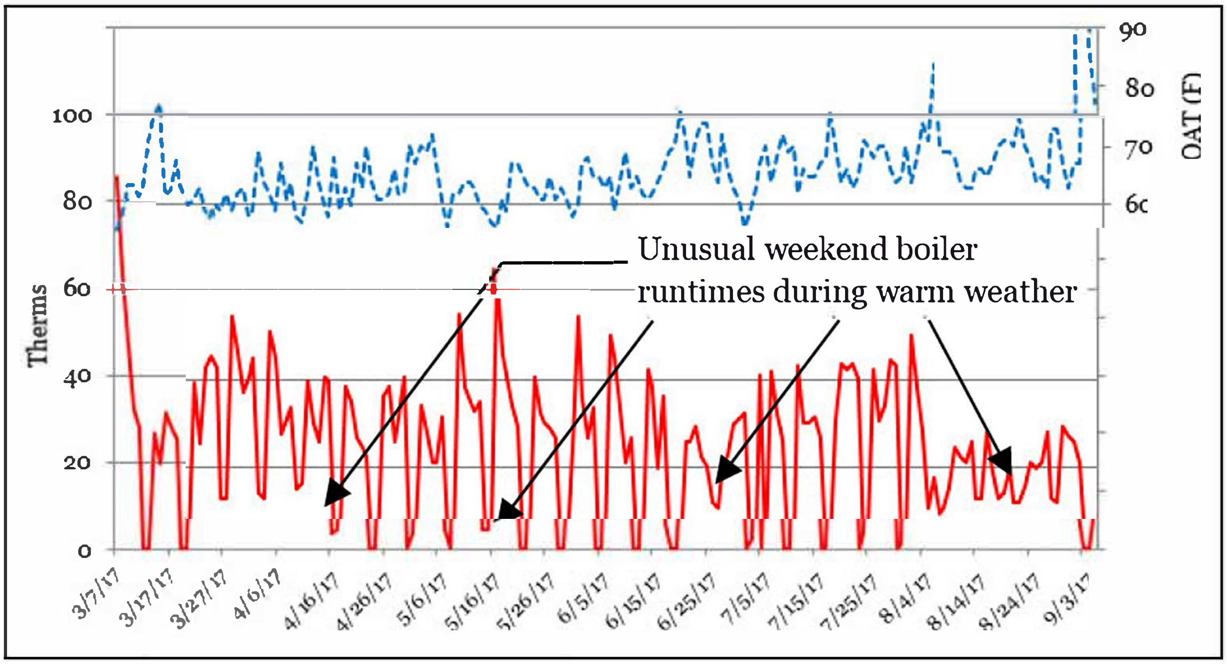
$$\frac{1.08 \times 15{,}200 \text{ CFM} \times (69\text{F} - 55\text{F})}{100{,}000 \times 0.71} \times 390 \text{ hrs} \times 0.85 = 1{,}070 \text{ th} = \$1{,}170$$

1.1.4 Hot Water System Enable Corrections

Recommended Execution: BAS Programmer | Targeted Systems: Hot Water

Calculated Savings: $2,160/yr (177,000 kBtu/yr) | Cost Estimate: $0 (immediate PB)

Figure 4 Daily gas consumption for 6 months plotted with average outside air temperature



ECM Description:

Recently available daily natural gas data indicated erratic boiler operations at Building 613. The hot water boiler should not be coming on during unoccupied times throughout spring and summer months of mild weather as shown above.

After observing the boiler and pump systems enabled after hours during the most recent site visit, the culprit was found to be in the enable sequence. BAS logic had been setup during construction to enable the boiler off any single VAV box calling for more than 15% of its configured heat load. Several faulty boxes were found outputting erroneous capacity values and randomly bringing the hot water system on with all AHUs off. The sequence was improved to ignore box demands during unoccupied hours and faulty boxes were recommissioned.

Calculations:

The fix was made on-site with DPW and BAS staff present, so no implementation costs were incurred. Since the 6 months of interval data makes it easy to observe weekend runtimes, however, the below calculations capture the estimated price for this erratic boiler and pump behavior. It is unknown how long this problem has existed, however results are most likely conservative since additional weeknight operations were observed.

Annual Boiler Savings:

4.7 th/day x 365 day/yr = $1,730 th = $1,900

Annual Pump Savings:

$$\frac{53\ \text{GPM} \times 97\ \text{ft}}{3{,}956 \times 0.51} \times 0.746 \times 592\ \text{hrs} = 1{,}160\ \text{kWh} = \$260$$

1.1.5 Duct Static Pressure Setpoint Reset

Recommended Execution: BAS Programmer   Targeted Systems: AHU 1-4

Calculated Savings: $1,770/yr (29,390 kBtu/yr)   Cost Estimate: $1,200 (< 1 yr SPB)

Table 1 Fan savings calculations were performed by temperature bin

Temp Bin	Total Flow (CFM)	Design Pressure (in w.c.)	Reset Pressure (in w.c.)	Air-Side Efficiency	Bin Hours	Savings (kWh/yr)	Savings ($/yr)
60F-65F	15,200	1.15	0.6	37%	617.5	1,630	$334
55F-60F	21,975	1.15	0.63	40%	690	2,324	$476
50F-55F	28,740	1.15	0.66	42%	582.5	2,267	$465
45F-50F	35,510	1.15	0.69	45%	290	1,232	$253
40F-45F	42,285	1.15	0.72	48%	185	826	$169
35-40F	49,055	1.15	0.75	49%	70.5	331	$68
Total					**2,435.5**	**8,610**	**$1,770**

ECM Description:

Since the constant duct static pressure setpoint being maintained 2/3 down the duct length for each AHU was designed for the 1% cooling condition (74F in Monterey), at all outside air temperatures below this design extreme we can expect that the duct static setpoint is unnecessarily high. Thus, the duct static setpoint reset strategy automatically adjusts this setpoint to the minimum amount that keeps zone CFMs satisfied.

This ECM was implemented during the RCx Assessment. The BAS programmer tasked to restore BAS functionality used the remaining time on site (approximately 8 hours) to modify each AHU's sequence of operation to reset duct static setpoint based on max zone damper position. Less critical zones were excluded from this sequence (bathroom, corridor, and storage spaces) however diligence is required to ensure other rogue zones are not unnecessarily limiting savings potentials.

Calculations:

Since outside air temperature is the predominant driver for AHU 1-4's almost exclusively perimeter spaces, Monterey bin hours were applied to anticipated AHU fan equation parameters within each temperature bin. Bin hours were adjusted for the new runtimes generated from holiday/zone scheduling, demand controlled ventilation and start-up improvement ECMs. Lower CFM values from the dual minimum flow setpoint ECM were proportionally included as bin temperatures approached an assumed building balance condition of 65F outside air.

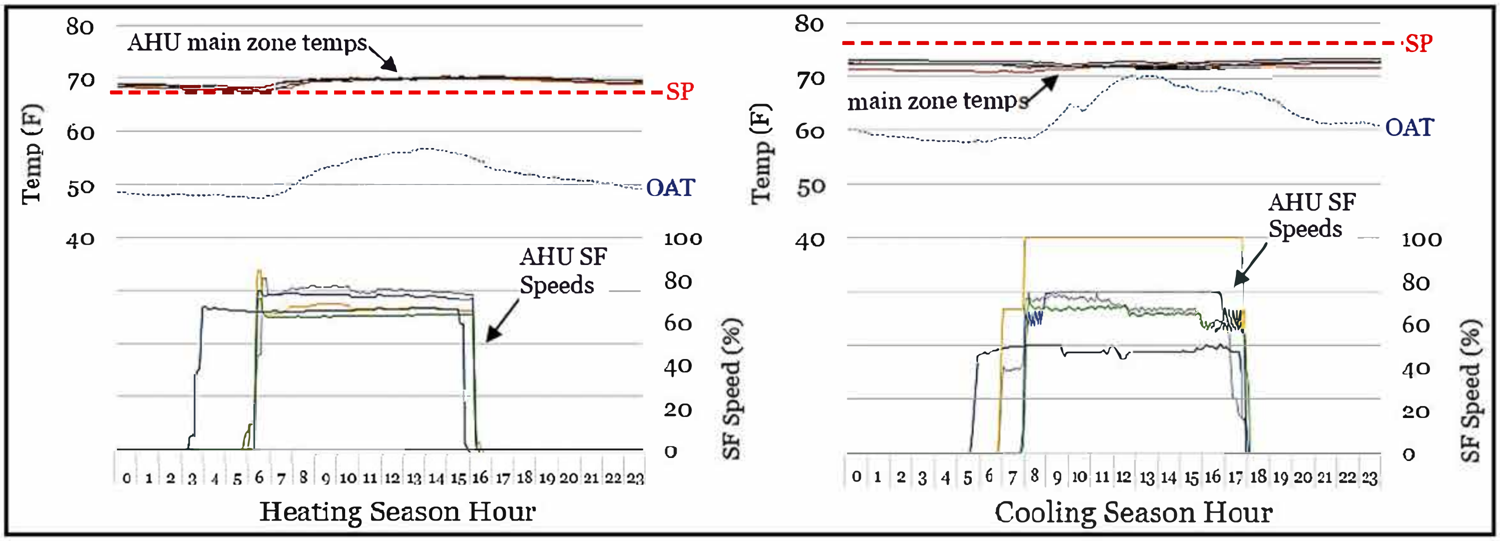
Savings were less than expected based on initial calculations from the RCx Assessment Phase due to these ECMs as well as for a number of other reasons. There is a relatively high chiller lockout, lower than average electrical rates were used (assuming less reset during summer), design duct static pressure setpoint was fairly low, and a minimum of 0.5 in w.c. was determined necessary to maintain minimum pressure at ceiling diffusers.

1.1.6 Improved AHU Start-Up Sequences

Recommended Execution: BAS Programmer — Targeted Systems: AHU1-4

Calculated Savings: $440/yr (6,900 kBtu/yr) — Cost Estimate: $300 (< 1 yr SPB)

Figure 5 Average heating season vs cooling season AHU start-up, operating, and shut-down conditions



ECM Description:

AHU units are enabled well ahead of building occupied times (7:15am) despite zone temps at or above setpoints in main zones (hallways with some perimeter exposure). There are three causes: BAS schedules were non-uniform, BAS controller time clocks were inaccurate, and warm-up optimization logic is inappropriately employed. As an example, one unit with a BAS clock 30 minutes fast was scheduled to start at 5am using up to 1 hour warm-up sequences resulting in 3:30am enables.

Controller schedules have been reconfigured for 7am starts and timeclock have been resynchronized with the BAS server (both through existing BAS plug-ins). Remaining implementation is for roughly 2 hours of BAS programmer work to reduce potential warm-up windows to 30 minutes, ensure warm-up mode occupied setpoints are at 68F, and remove or permanently disable unnecessary cooldown sequences.

Calculations:

Primary energy savings for reducing unnecessary morning warm-up times are in fan power savings. For calculation purposes, duct static pressure is assumed at minimum setpoint during warm-up, total heating CFMs are used, and an average daily runtime prior to 7am was generated from fan data.

AHU 5 savings were not calculated to avoid overlap with the DCV ECM. Savings are conservative given that no natural gas reduction is considered despite observing different modes of outside air damper failure throughout the year. With damper actuator, linkage, and seal repair, outside air dampers should remain closed during warm-up as programmed to prevent unnecessary ventilation loads while unoccupied.

Annual Fan Savings:

$$\frac{49{,}055 \text{ CFM} \times 0.75"}{6.356 \times 0.49} \times 0.746 \times 230 \text{ hrs} = 2{,}020 \text{ kWh} = \$440$$

1.1.7 Scheduled DHW Operation

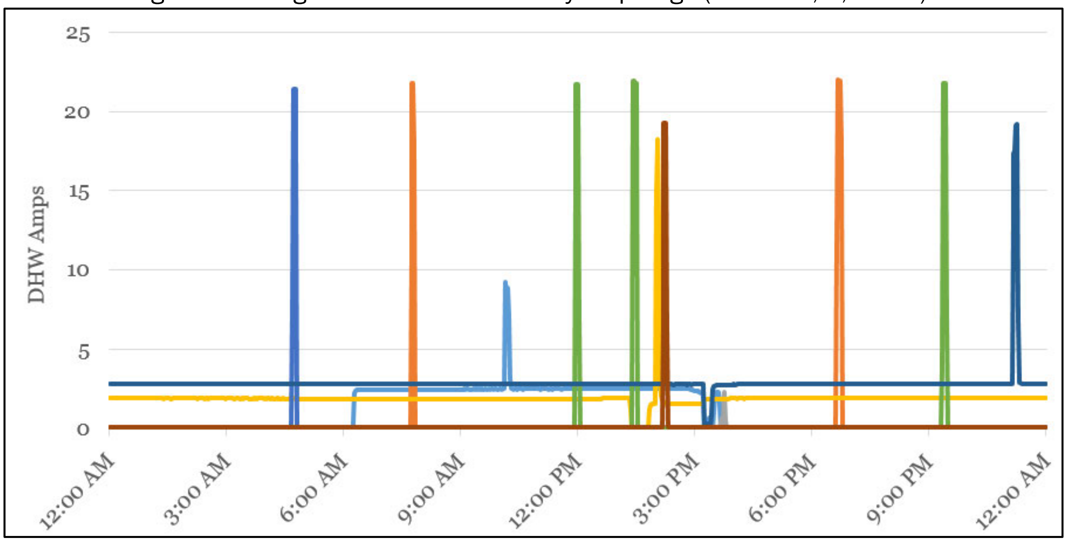
Recommended Execution: O&M Work Orders

Targeted Systems: DHW Units

Calculated Savings: $2,850/yr (0 kBtu/yr)

Cost Estimate: $4,290 (1.5 yr SPB)

Figure 6 Average electric DHW weekday amperage (DHW 1-6, 8, and 9)



ECM Description:

Amperage trend data suggests water heater recharge times occur throughout each PG&E-defined daily peak period of 12pm-6pm. We recommend installing digital timeclocks for two sample units (relative higher use WH-6 and breakroom WH-10) to schedule units off during these peak periods to avoid electrical demand charges. If ASHRAE Standard 188 (Legionella Risk Management) recommendations of 108F+ storage temps cannot be maintained, consider iteratively raising setpoint. Repeat work order for remaining units.

Due to the inactive status of 1st floor showers, we recommend decommissioning WH-3 via electrical disconnect, isolation valves, and draining. South-facing restrooms currently served by WH-3 (rooms 145 and 147) can have a single sink in each bathroom retrofit with an under-sink point-of-use water electric heater.

Calculations:

Demand savings are calculated for three-phase high voltage power assuming each monthly peak can be reduced by at least one water heater's operational amperage. Power factor for electric resistance heating is 1.0.

These savings are conservative given that only non-coincident DHW runtime is considered. Furthermore, tank/distribution losses and maintenance savings for WH-3 were assumed minor give the current piping distances, no return pump, and unit age/condition and thus not calculated.

Electrical Demand Savings:

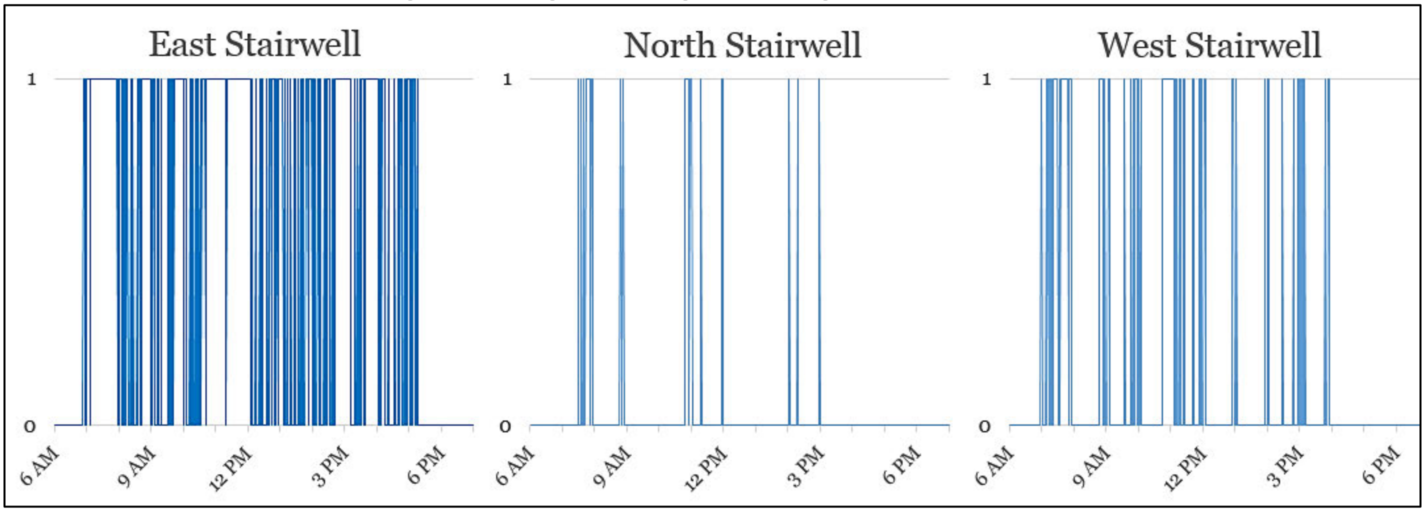
$$\frac{21.75\ amps\ x\ 480V\ x\ 1.0\ x\ \sqrt{3}}{1{,}000} = 18.1\ \text{kW x 12 mo} = \$2{,}850$$

1.1.8 Demand-Based Stairwell Lighting

Recommended Execution: O&M Work Orders | Targeted Systems: Stairwell Lights

Calculated Savings: $1,920/yr (29,790 kBtu/yr) | Cost Estimate: $11,350 (6 yr SPB)

Figure 7 Average daily usage of Building 613's three stairwells



ECM Description:

Stairwell lights are currently operated as 24/7 emergency fixtures for Building 613's three curtain-walled stairwells. Data logging within these stairwells reveals low average daytime usage, except at the 1st floor East stairwell (main entrance). A single retrofit to LED bi-level motion and daylight-controlled emergency fixtures will reduce light levels to minimum National Fire Protection Agency (NFPA) 101 code compliance (1 foot candle) with no motion, disable lights when daylight is available, and decrease rated fixture power from 60W to 20W when in use. Coordinate changes with Safety Manager and Security Officer.

Implementation is recommended as separate non-interdependent work orders, else use capital improvement or 3rd party finance mechanisms. Retrofit assemblies are available at 120-277V operation for $500 with 30 minutes of electrician labor estimated per fixture.

Calculations:

Using as-built equipment schedules and known 24/7 operation, baseline annual energy usage for 21 2-lamp fluorescent stairwell fixtures is 11,050 kWh. Primary savings are from daylight control (all stairwell spaces besides the top landing receive greater than 10 foot candles during daylight hours) and motion control (for nights, weekends, and unused daytime periods). Secondary savings from fluorescent-to-LED operation when stairwells are in use, electric demand reduction, and lamp replacement labor savings are minor and are not included below.

Annual Daylight Savings:

60W x 18 fixtures x 2,190 hrs = 2,370 kWh = $520

Annual Motion Savings:

Off Hours: 55W x 21 fixtures x 5,050 hrs 5,835 kWh = $1,280

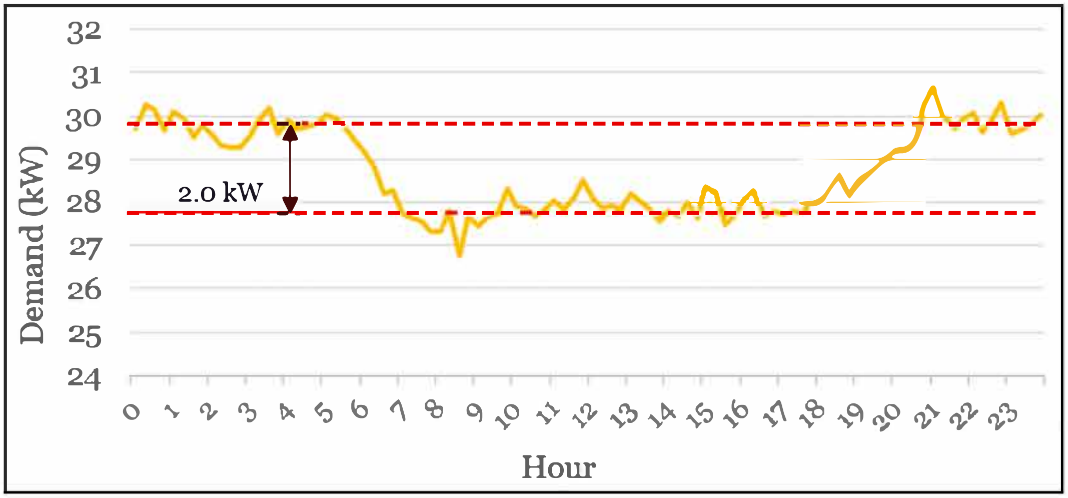
Building Hours: 55W x 21 fixtures x 850 hrs 990 kWh = $220

1.1.9 Exterior Lights Late Night Shutoff

Recommended Execution: O&M Work Order — Targeted Systems: Exterior Lights

Calculated Savings: $800/yr (12,400 kBtu/yr) — Cost Estimate: $490 (< 1 yr SPB)

Figure 9 Average weekend day vs night electrical demand reveals exterior light load



ECM Description:

Though benchmarking indicated early that exterior lighting does not represent a major energy user at Building 613, the installation has an energy policy to reduce night lighting between the hours of 11:30pm and 4:30am when cost-effective and approved by the base Safety Manager and Security Officer.

Implementation requires a single 3-channel time clock mounted at or near the SHH sub-panel in the 1st floor electrical room. We recommend a work order through the base operations contract to move the 20-amp exterior lighting circuits 2, 4, and 6 onto a new astronomical timeclock programmed with the installation's standard late night disable schedule as a second layer of lighting control along with the existing photocell. These circuits control courtyard, walkway, and down lights. Site bollards appear to be non-operational.

Calculations:

With interval kW data available for the previous year, the annual energy savings is simply the difference between the average night load of 29.8 kW and average weekend day of 27.8 kW times the 5 hours of late night shutdown equals 3,630 kWh or $800.

Figure 8 Coordinate with safety/security stakeholders

1.1.10 Light Fixture LED Retrofits

Recommended Execution: Electrical Contractor Targeted Systems: Interior Lights

Calculated Savings: $27.7K/yr (353,260 kBtu/yr) Cost Estimate: $70.3K (2.5 yr SPB)

Table 2 Savings and costs associated with fluorescent to LED lighting fixture retrofits

Space Type	Space Usage Factor	Fixture Count	Fixture Watts	LED Fixture Watts	Demand Savings (kW)	Electrical Savings (kWh/yr)	Total Savings ($/yr)	Retrofit Materials	Retrofit Labor	Total Cost
Corridor	85%	95	120	72	3.9	10,175	$ 2,849	$ 3,040	$ 1,900	$ 5,805
Office	65%	342	120	72	10.7	28,010	$ 7,842	$ 10,944	$ 6,840	$ 20,896
Bathroom	80%	70	30	18	0.7	1,764	$ 494	$ 560	$ 1,400	$ 2,303
Auditorium	42.5%	48	120	72	1.0	2,570	$ 720	$ 1,536	$ 960	$ 2,933
Breakroom	20%	25	120	72	0.2	630	$ 176	$ 800	$ 500	$ 1,528
Conference	25%	44	120	72	0.5	1,386	$ 388	$ 1,408	$ 880	$ 2,688
Classroom	55%	408	120	72	10.8	28,274	$ 7,916	$ 13,056	$ 8,160	$ 24,929
Emergency	24/7	73	120	72	3.5	30,695	$ 7,305	$ 5,621	$ 2,190	$ 9,178
Total		**1,110**	**870**	**520**	**30.0**	**103,500**	**$ 27,690**	**$ 36,970**	**$ 22,830**	**$ 70,260**

ECM Description:

Since the initial design of Building 613, the price of LED lighting technology has dramatically reduced. This provides the opportunity for a retrofit of the predominantly 4 foot, 4-lamp fluorescent lighting fixtures. Using space usage factors collected during the RCx process, the economics on this effort suggest strong justification for a capital improvement project despite the facility's recent construction.

Implementation assumes installation of 4 new 18W LED bulbs ($8 each) and removal of the electronic ballast in each fixture. Due to low usage, electrical/mechanical rooms, storage areas, bathroom can lights, and attic lights are not included (as-fails retrofit via work order is recommended). Ceiling heights are between 8 and 12 feet; 20 minutes is the estimated electrician labor per fixture (30 mins for new emergency ballasts).

Calculations:

Savings are from reduction of electrical load that decrease both electrical and demand-based charges. Existing fixtures use 30W fluorescent lamps (ballast load is assumed minor). Ballast-less LED replacements are available at 18W at identical color temperature can comparable lumen output.

Usage factors were generated from a combination of occupancy data logging, known schedules, and observed utilization patterns. Most fixtures operate significantly less than the building's overall schedule due to transient usage, lower than design occupancy, and existing vacancy sensors. Emergency fixtures operate 24/7.

Since the retrofit effort would be accomplished via capital improvement, project cost factors were added including a 17.5% markup for contractor overhead, profit, and bonding. While 3rd party financing is an option, we recommend contracting directly to an electrical contractor due to the efforts overall simplicity and repetitiveness.

Final RCx Measures List

Building: ______##______

Monitoring Plan POC: ___-----_____

Date: __5/30/17__

Execution	ECM	Savings				Impele-mentaton	Pay-back (yrs)	Status
		kWh	therms	kBtu	$			
BAS Operator	Ventilation Airflow Setpoint Adjustments	20,260	1,490	218,100	$6,090	$3,600	0.6	Recommended
BAS Operator	Auditorium Demand Controlled Ventilation	2,780	1,660	175,500	$2,430	$600	0.2	Recommended
BAS Operator	Zone-Level Classroom Scheduling	4,690	1,070	123,000	$2,200	$600	0.3	Recommended
BAS Operator	Hot Water System Enable Corrections	1,160	1,730	177,000	$2,160	$0	0.0	Complete
BAS Operator	Duct Static Pressure Setpoint Reset	8,610	-	29,390	$1,770	$1,200	0.7	Complete
BAS Operator	Improved AHU Start-up Sequences	2,020	-	6,900	$440	$300	0.7	Recommended
Work Order	Scheduled DHW Operation	-	-	-	$2,850	$4,290	1.5	Recommended
Work Order	Demand-based Stairwell Lighting	8,730	-	29,790	$1,920	$11,340	5.9	Recommended
Work Order	Exterior Lights Late Night Shutoff	3,630	-	12,400	$800	$485	0.6	Recommended
Energy Project	Light Fixture LED Retrofits	103,500	-	-	$27,690	$70,260	2.5	Recommended
Total		**155,380**	**5,950**	**772,080**	**$48,350**	**$92,675**	**1.9**	**-**

Issues & Resolutions Log

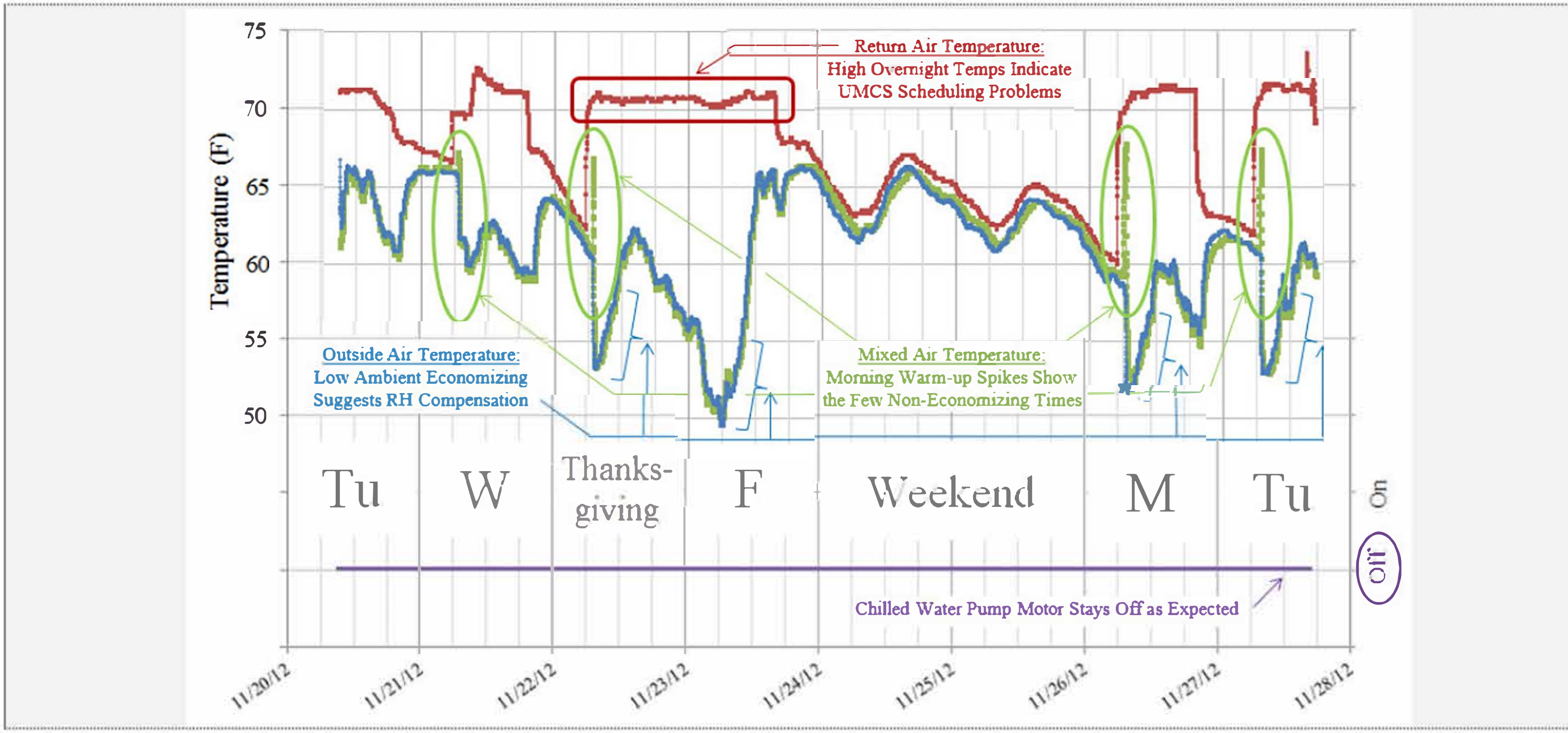
Building: ##

I&R Log POC: ------

Date: 2/2/17

Issue #	System/ Equipment	Issue	Resolution	POC/Date
1	ChWS	MCC H-O-A is in "OFF"	H-O-A is not connected inside MCC, O&M to blank H-O-A module	Lang/ 2FEB17
2	Cisterns	Day tank is favoring city rather than cistern water due to configuration requiring minimum 40% full cistern	configuration lowered to 20% for cistern valve enable (to protect against sediment)	Tulley/ 3FEB17
3	AHU-3	OAD actuator bracket has sheared off (actuator assembly is spinning freely)	Tulley to submit service request to repair and survey remaining econo dampers	Tulley/ 3FEB17
4	HWS	Boiler is cycling: approximately every ten minutes, causing excess purge losses	Clark investigate max HWP speed allowed to maintain boiler min capacity	Clark/ 3FEB17
5	all AHUs	majority (approx 35%?) CO2 sensors showing erroneous values (> 2,000 CFM)	all CO2 control to VAV box and economizer min OA reset removed except for 9 critical zones (calibration needed)	Lefebvre/ 2FEB17
6	all AHUs	holiday exceptions are limited and expired	OPM holidays for 2017-2022 are being added to AHU-2, 3, 4, and 5 scheduler LNS plug-ins	Tulley/ 3FEB17
7	Envelope	interior roof insulation has fallen (approx 50 SF)	Tulley to submit service request to repair	Tulley/ 3FEB17
8	all AHUs	conflicting min OAD setpoint (15%) and min OAF setpoints (200 CFM)	Clark investigate resizing OAF requirements, removed OAD min, and optimize econo control strategy	Clark/ 3FEB17
9	ATUs	zone setpoints set to 68F/78F +/-3.6F (should be 68F/76F +/-2F base standard)	Tulley to delegate plug-in reconfigurations	Tulley/ 3FEB17
10	Energy Meter	faulty kW readings	Wattnode LNS plug-in had been configured for CT of 2 A, corrected to 2000 A	Lang/ 2FEB17
11	ATU-202E	failed box (erroneous readings, i.e. zone temp at 630F)	box is communicating correctly after recommissioning the device	Clark/ 3FEB17
12	AHU-4	high limit discharge set to approx 4" (fan design is 6.5") and VFD has configured high limit of 50 Hz (trips at 60Hz)	Clark to investigate higher VFD ramp speed configuration and HL setpoint above design	Clark/ 3FEB17
13	HWS	pump time delay was duplicated in logic	redundant stop delay block was removed	Clark/ 3FEB17

Endurance Test - Equipment Level



Use your endurance trend data to any answer the following questions as applicable:

1	Does your endurance test indicate if your ECM was implemented correctly?	The above trend indicates that the air-side economizer is NOT performing correctly.
2	Describe what if any actions need to be taken?	Institute exception holiday scheduling for this AHU. Reprogram economizer temperature loop control to track SAT setpoint or otherwise investigate low OA economizing. Disable economizing during warm-up mode.
3	Are any restests needed? If so, specify how to accomplish this.	Make the above corrections and retest. Provide minimum one-week performance trends for each OAT/MAT/SAT and ChWP status AHU point. Force holiday scheduling and OAT > econo lockout if not observable during testing.
4	Are any future off-season, check-up, or OCx tests needed?	Perform follow-on testing if above retests are not conclusive, else replicate economizer tests/trends at least twice annually to check for failed dampers, sensor issues, scheduling errors, or non-optimum programming.
5	Are any changes to controls graphics, alarms, overrides or trends needed?	Change BAS trend intervals on all economizer analog input points from 15 to 5 minutes. Provide new graphics table that summarizes operation of all air-side unit including econo temps, damper positions, and fan runtimes.

Post-Implementation RCx Meter Data