ASHRAE Illinois Spring Conference

Retro-Commissioning (RCx) of Hydronic Systems - A Hands-On Approach

Fiona Martin, P.E., QCxP, BEAP, LEED AP O&M
Project Engineer

Tim Shinnick, P.E., QCxP, LEED AP
Project Engineer

Grumman/Butkus Associates
Energy Consultants
Design Engineers

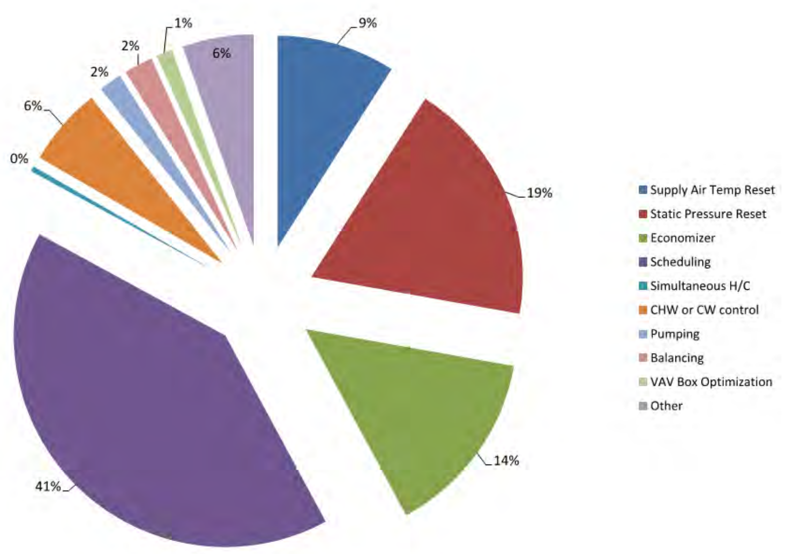
ASHRAE Illinois Chapter

Objectives

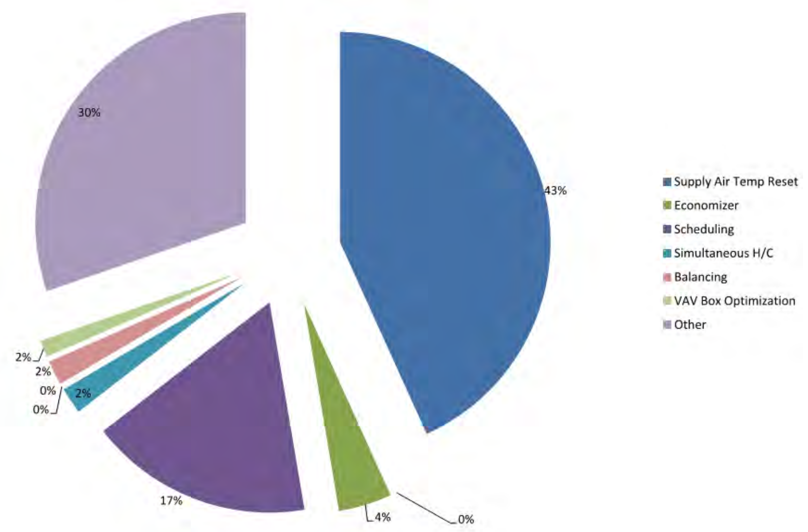
- **Discuss energy audit and RCx investigation practices**
- **Discuss chilled water, hot water and steam systems.**
- **Discuss possible energy conservation measures for different hydronic systems**
- **Discuss examples of implemented measures and M&V procedures**

Why Additional Attention is Required

Distribution of RCx Electricity Savings



Distribution of RCx Natural Gas Savings



RCx versus Auditing

Energy Audit

- Limited time to investigate
- Review utility data
- Attention to capital-intensive projects.

Retro-Commissioning

- Detailed investigation
- Review utility data
- Functional testing
- Target low-cost measures
- Continue project from identification to implementation and M&V.

Data Collection

- Equipment nameplate data
  - model number, serial number, capacity
- Pump information
  - horsepower, flow, head, motor efficiency
- Temperature setpoints
- Supply and return temperatures
  - Water temperature in and out of coils
  - Air temperature before and after coils
- Pressure setpoints

Tools for Data Collection

- Temperature sensors
- Pressure gauges
- Data loggers
- Thermal camera
- Flow meter

Functional Testing

- **Stroke control valves**
  - Does the valve respond to the control system?
  - Does the valve close completely?
- **Change temperature or pressure setpoints and monitor system**
  - Make small changes to setpoint
- **Sensor calibration check**
  - Is the sensor location appropriate?

Temperature Sensor Application

Functional Testing

- **Record initial conditions**
  - Take screenshot of BAS or field measurements
  - Record of pre-test conditions and settings
  - Something unexpected may happen

Functional Testing

Look inside the equipment if possible

RCx/Audit Checklist

ENERGY AUDITOR CHECKLIST					
C. HVAC -- CONTROLS	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
13. Control devices are not inspected on a regular basis.	[ ]	[ ]			
Suggested O&M:					
a. Routinely check all time clocks and other control equipment for proper operation, correct time and day and for night and proper programming of on-off set points. Protect from unauthorized adjustment.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Use an automated energy management system.			[ ]	[ ]	[ ]
14. Building temperatures are not adjusted for unoccupied periods.	[ ]	[ ]			
Suggested O&Ms:					
a. Reduce thermostat settings by a minimum of 10ºF at nights, for weekends and holidays during heating season, but maintain ventilation..			[ ]	[ ]	[ ]
b. Shut down air conditioning units at night, on weekends and holidays.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install automatic controls such as time clocks or automated management systems.			[ ]	[ ]	[ ]
15. Unoccupied or little used areas are heated or cooled unnecessarily.	[ ]	[ ]			
Suggested O&Ms:					
a. Reduce winter thermostat settings to 55ºF in unoccupied areas.			[ ]	[ ]	[ ]
b. Where possible, turn off heating systems if nothing ;in space can freeze.			[ ]	[ ]	[ ]
c. Use spot heaters/coolers in large spaces with low occupancy.*			[ ]	[ ]	[ ]
d. Increase summer thermostat setting, in unoccupied areas, if possible.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install system controls to reduce heating/cooling of unoccupied spaces.			[ ]	[ ]	[ ]

RCx/Audit Checklist

- **Have a list of field data to collect**

  → Generate equipment list

- **Recommendations to Investigate**
  - O&Ms (fix-it/maintenance items)

    → Develop Issues Log
  - RCMs (low-cost investment/short term payback)
  - ECMs (capital investment/long term payback)

Chilled Water Systems

Get familiar with the system

- Identify the system configuration
  - constant primary, variable secondary
  - How many secondary loops?
- Are there two-way valves or three-way valves on equipment?
- What is the chilled water setpoint?
- What is the condenser water setpoint?
- How are the pumps controlled?

Chilled Water Systems

Get familiar with the system (continued)

- Is there a decoupler or bypass?
  - Where is it? How was it installed?
- What is the typical maximum/minimum load?
  - How many chillers and towers typically operate?
- How are chillers staged?
- How are the cooling towers staged?

Chilled Water Systems

Potential Energy Conservation Measures

- Open triple duty valves
  - trim impeller or install VFDs
- Replace failed temperature or differential pressure sensors
- Chilled water temperature reset
- Condenser water temperature reset
- Pump differential pressure reset
- Chiller staging modifications
- Increase chiller delta T
- Convert constant flow systems to variable flow
- Add free cooling heat exchanger
- Chiller VFDs or replacement

Chilled Water Systems

Chilled Water Systems

Things to consider for typical ECMs

- **Chilled Water Temperature Reset**
  - Warmer chilled water temp may increase pump energy
  - Warmer chilled water temp may reduce dehumidification
- **Condenser Water Reset**
  - What is the condition of the cooling tower?
  - Are the chiller savings greater than the increased tower fan energy?
- **Pump Differential Pressure Reset**
  - What is current setpoint?
  - Monitor AHU chilled water valve positions as pumps slow.

Chilled Water Systems

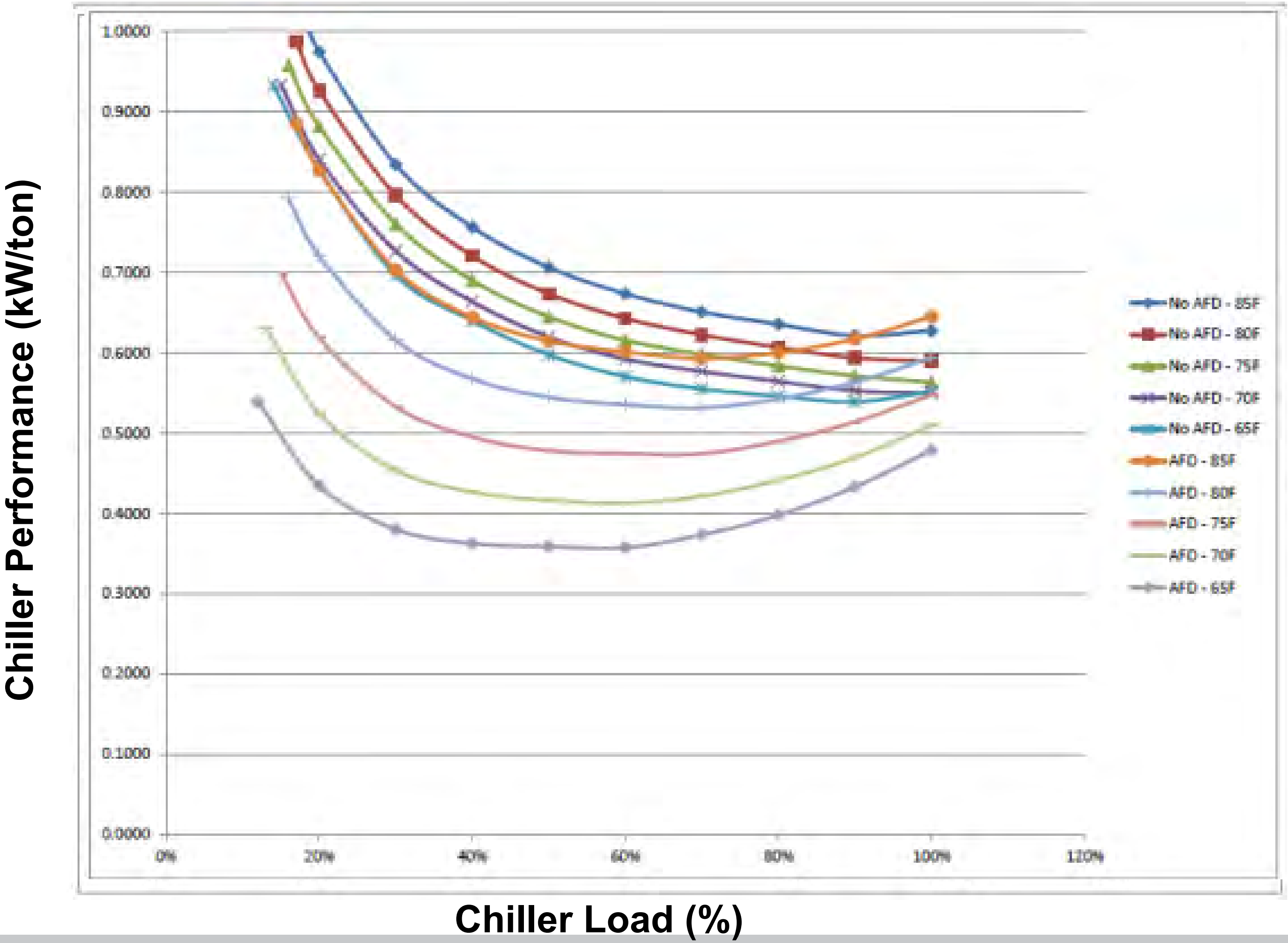
Ask for manufacturer performance data

Percent Load	100	%	90	%	80	%	70	%	60	%	50	%	40	%	30	%	20	%	11	%
Chiller Capacity	1,200	Tons	1,080	Tons	960	Tons	840	Tons	720	Tons	600	Tons	480	Tons	360	Tons	240	Tons	132	Tons
Chille Power Input (kW)	473	kW	382	kW	312	kW	258	kW	214	kW	181	kW	164	kW	144	kW	133	kW	131	kW
Cooler																				
Entering Temp	55.96	°F	54.77	°F	53.57	°F	52.38	°F	51.18	°F	49.98	°F	48.79	°F	47.59	°F	46.39	°F	45.32	°F
Leaving Temp	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F
Flow Rate	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm
Condenser																				
Entering Temp	73.84	°F	72.88	°F	71.96	°F	71.06	°F	70.18	°F	69.32	°F	68.49	°F	67.65	°F	66.83	°F	66.11	°F
Leaving Temp	65	°F	65	°F	65	°F	65	°F	65	°F	65	°F	65	°F	65	°F	65	°F	65	°F
Flow Rate	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm

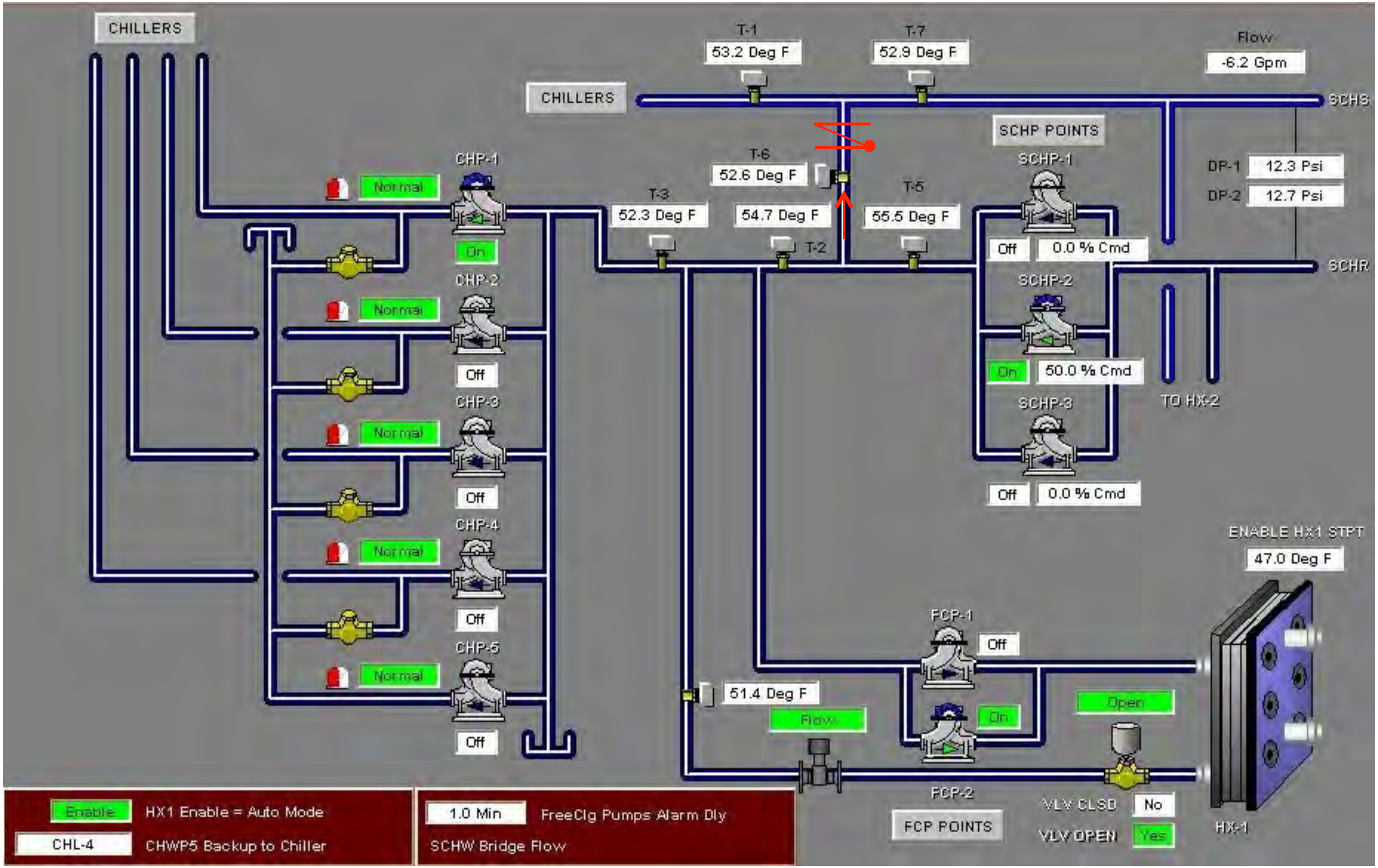
Percent Load	100	%	90	%	80	%	70	%	60	%	50	%	40	%	30	%	20	%	15	%
Chiller Capacity	1,200	Tons	1,080	Tons	960	Tons	840	Tons	720	Tons	600	Tons	480	Tons	360	Tons	240	Tons	180	Tons
Chille Power Input (kW)	434	kW	347	kW	288	kW	249	kW	214	kW	184	kW	156	kW	131	kW	106	kW	91	kW
Cooler																				
Entering Temp	55.96	°F	54.77	°F	53.57	°F	52.38	°F	51.18	°F	49.98	°F	48.79	°F	47.59	°F	46.39	°F	45.79	°F
Leaving Temp	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F
Flow Rate	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm
Condenser																				
Entering Temp	68.77	°F	67.82	°F	66.91	°F	66.04	°F	65.18	°F	64.32	°F	63.47	°F	62.63	°F	61.78	°F	61.36	°F
Leaving Temp	60	°F	60	°F	60	°F	60	°F	60	°F	60	°F	60	°F	60	°F	60	°F	60	°F
Flow Rate	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm	3600	gpm

Percent Load	100	%	90	%	80	%	70	%	60	%	50	%	40	%	39	%
Chiller Capacity	1,200	Tons	1,080	Tons	960	Tons	840	Tons	720	Tons	600	Tons	480	Tons	468	Tons
Chille Power Input (kW)	407	kW	299	kW	261	kW	228	kW	203	kW	185	kW	154	kW	152	kW
Cooler																
Entering Temp	55.96	°F	54.77	°F	53.57	°F	52.38	°F	51.18	°F	49.98	°F	48.79	°F	48.67	°F
Leaving Temp	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F	44	°F
Flow Rate	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm	2400	gpm
Condenser																
Entering Temp	63.71	°F	62.73	°F	61.86	°F	61	°F	62.42	°F	65.37	°F	63.32	°F	63.4	°F
Leaving Temp	55	°F	55	°F	55	°F	55	°F	55	°F	55	°F	55	°F	55	°F
Flow Rate	3600	gpm	3600	gpm	3600	gpm	3600	gpm	2500	gpm	1500	gpm	1500	gpm	1450	gpm

Chiller Curves



Chilled Water System Example 1



Chilled Water System Example 1

Baseline: In free cooling operation three pumps are active. Primary pump, secondary pump and heat exchanger pump

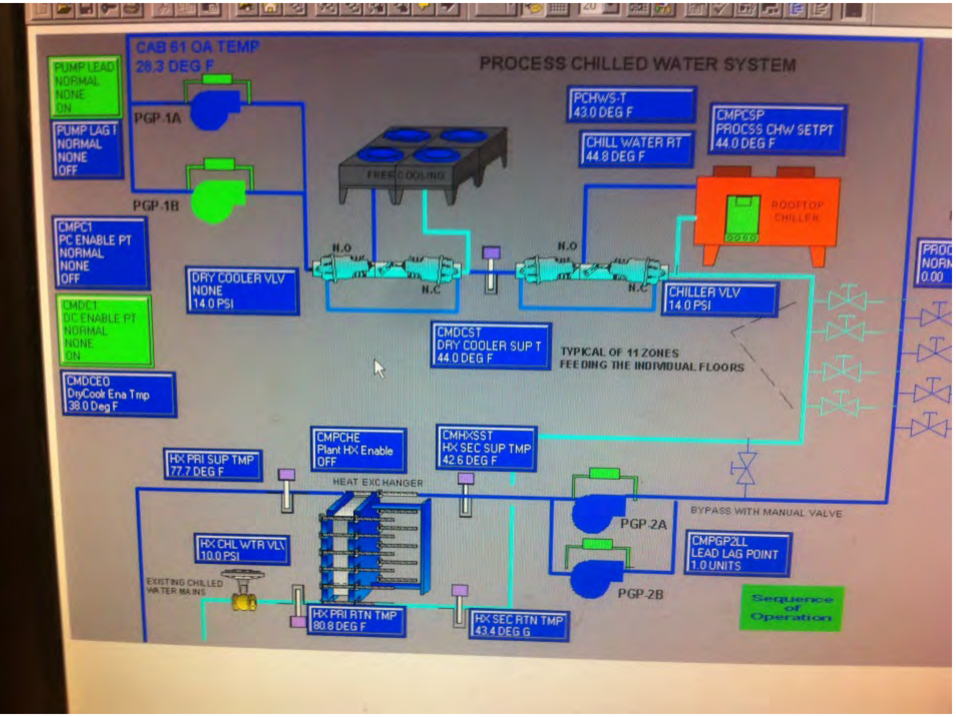
- Record pump operating power
- Trend pump status and speed

Implemented: Primary pump shuts off, secondary pump maintains differential pressure. Heat exchanger pump is active.

- Trend pump status and speed

Chilled Water System Example 2

Inspection of BAS



Valve Testing and Chiller Inspection

Hot Water Systems

Get familiar with the system

- What is the hot water supply temperature?
  - Is the temperature setpoint reset?
- Are there primary and secondary pumps?
- How are the pumps controlled?
- What is the typical load?
- How are the boilers staged?

Hot Water Systems

Potential Energy Savings Measures

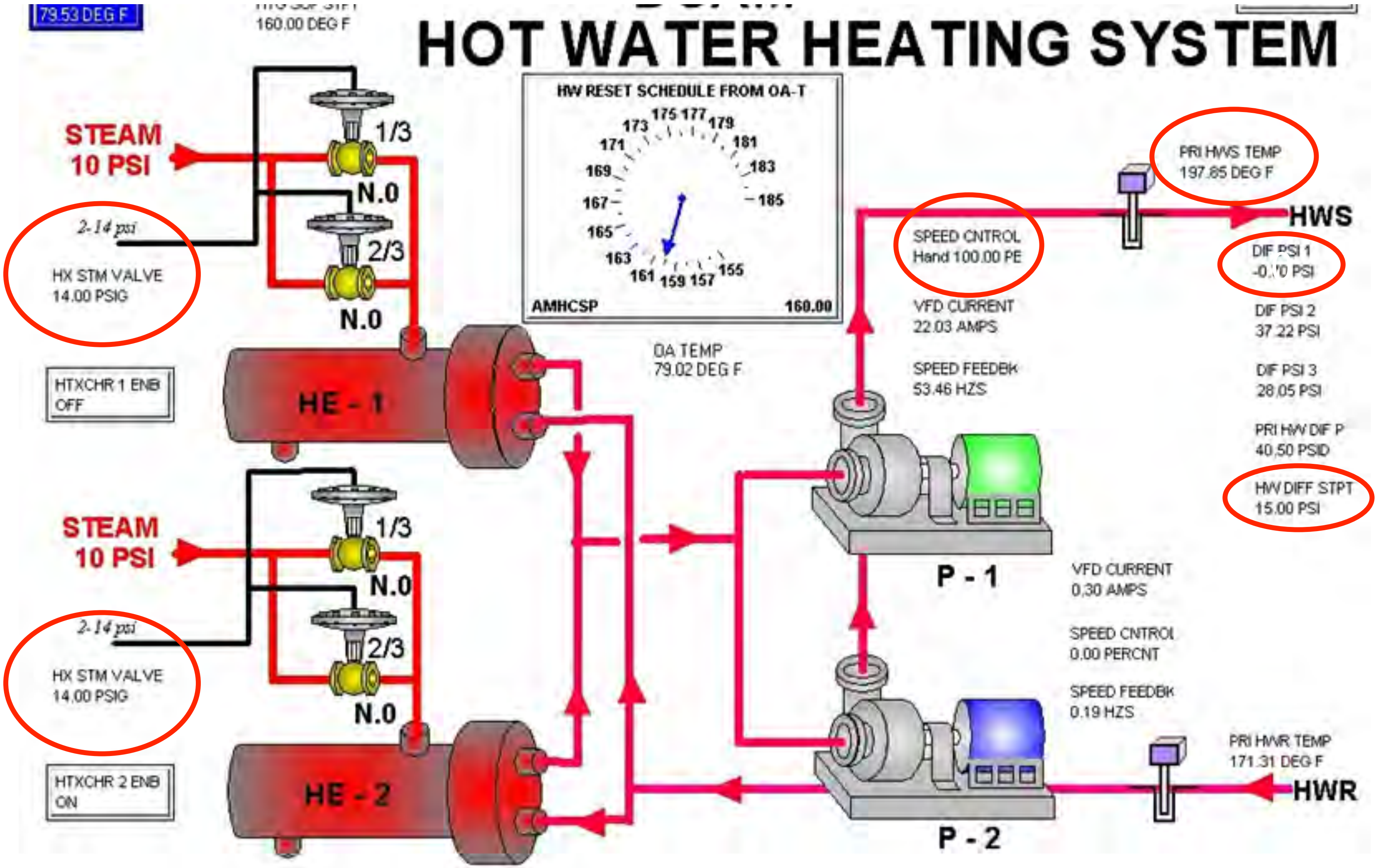
- Hot water temperature reset
- Perimeter baseboard pump control
- Freeze protection pump control
- Pump differential pressure reset
- Simultaneous heating and cooling
- Boiler staging
  - Reduce cycling on/off, reduce standby losses

Hot Water Systems

Things to consider for typical ECMs

- **Hot Water Reset**
  - Potential pump energy increase
  - Can the load still be maintained?

Hot Water System Example



Variable Speed Pump Control

Baseline: Pump operates at 100% at all times.

- Install data logger to record pump amps
- Trend the zone differential pressure setpoint and pump speed

Implemented: DP sensor was replaced and the pump began modulating speed to maintain the DP setpoint

- Trend the pump speed
- Estimate the pump power using the pump laws
- Normalize the pump power compared to outside air temperature

Repair Failed Valve Actuators

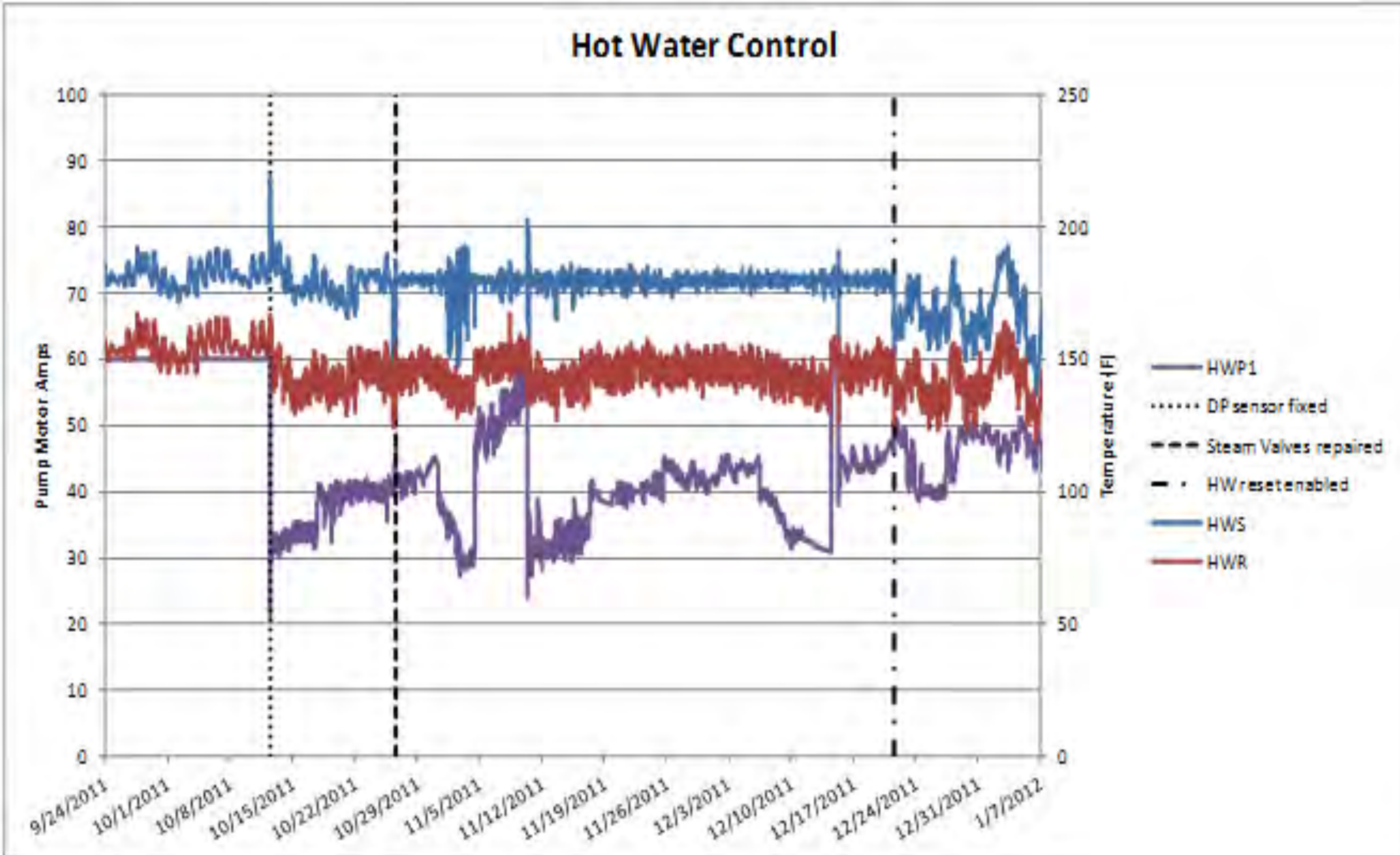
Baseline: Steam valves were open 100% at all times

- Trend hot water supply and return temperatures, steam valve command

Implemented: Valve actuator diaphragms were replaced, the system controlled temperature setpoint.

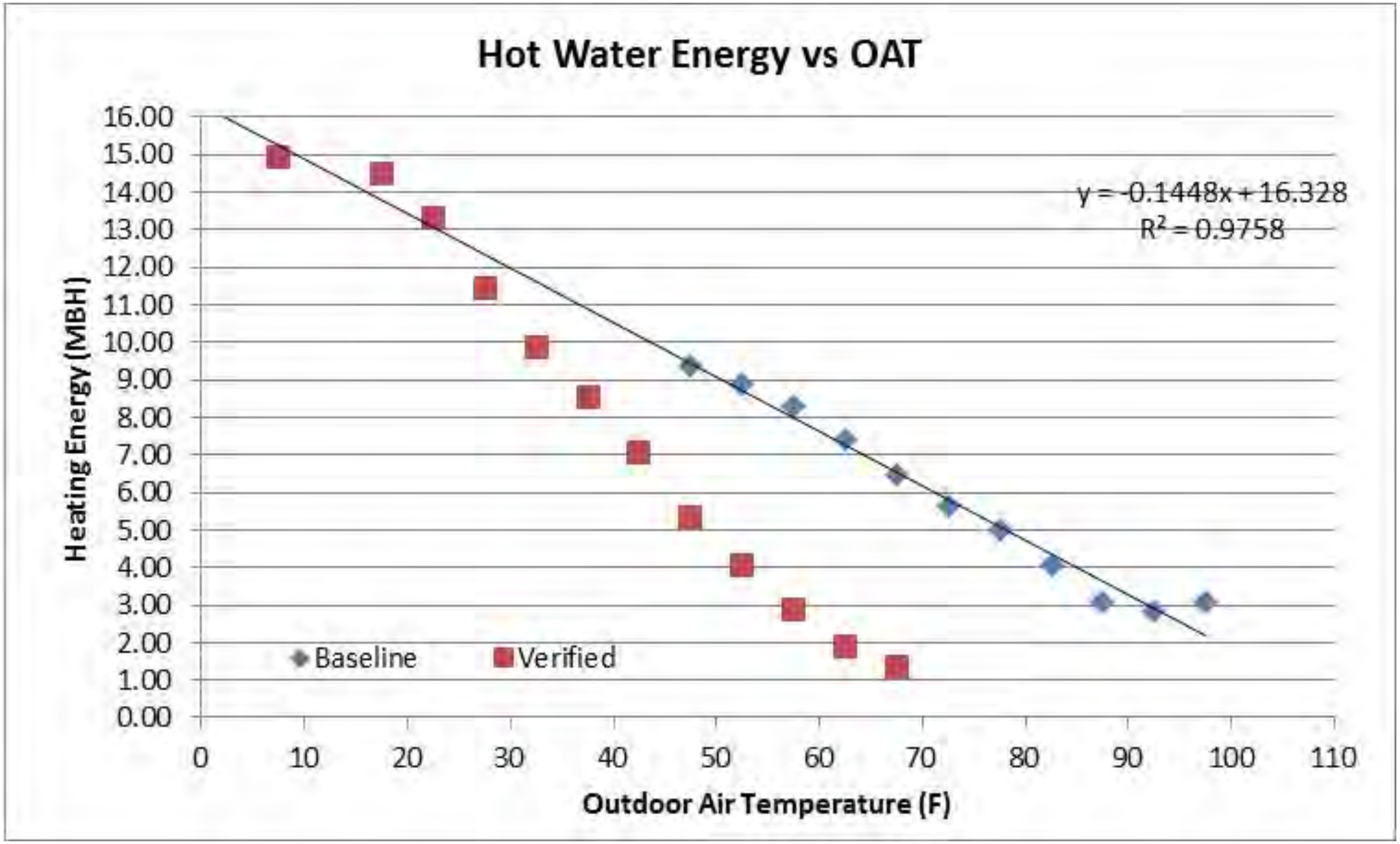
- Trend hot water supply and return temperatures, steam valve command
- Normalize the hot water load compared to outside air temperature
  - Assume the flow is proportional to the pump speed
  - Use the supply and return temperatures as system delta T

Verification Trend Data

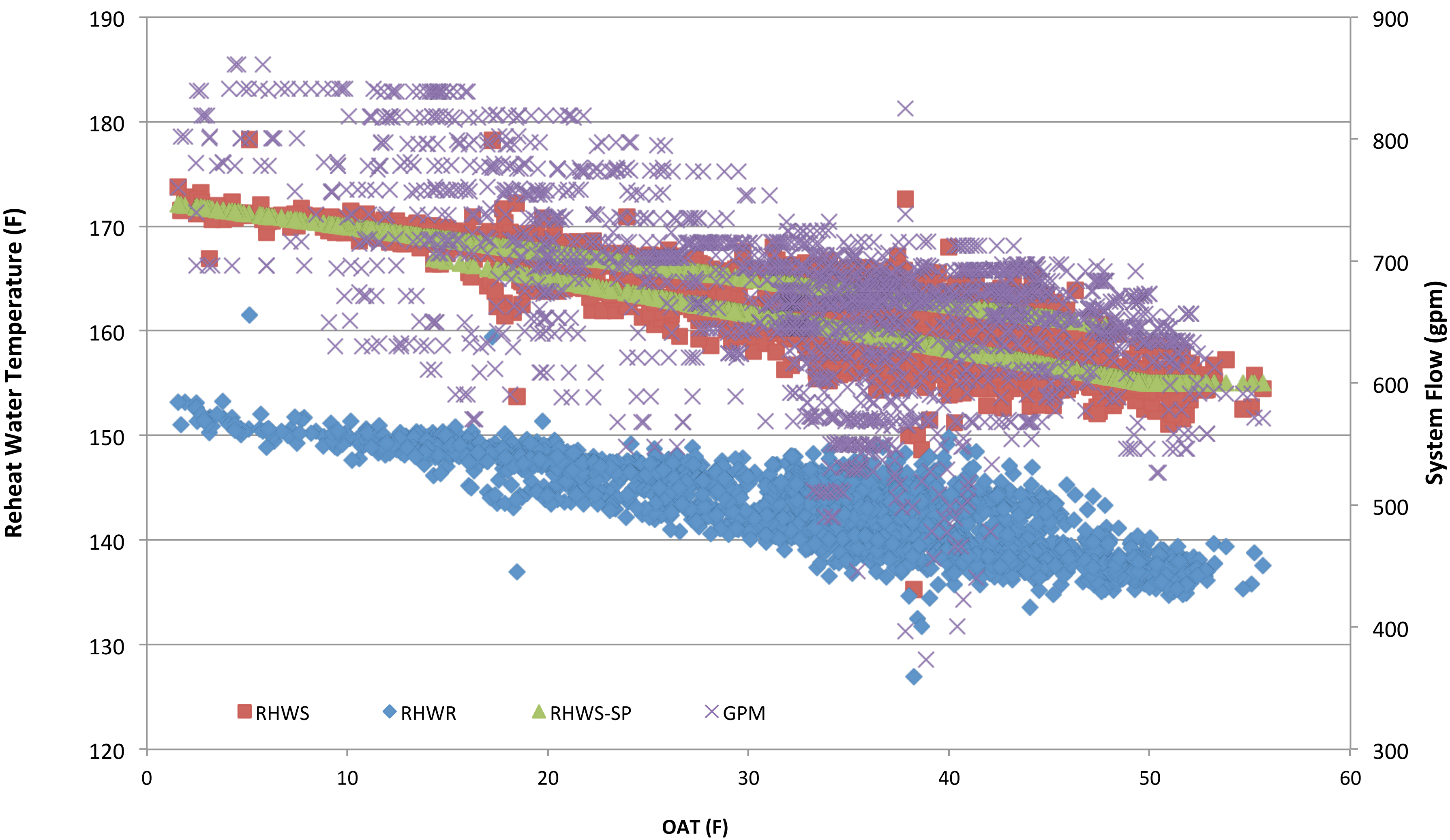


Verification Trend Data

Model the heating load compared to OAT



Data vs Outdoor Air Temp Example



Hot Water System Example

Estimated annual savings

- 218,000 therms
- 47,000 kWh
- $273,000

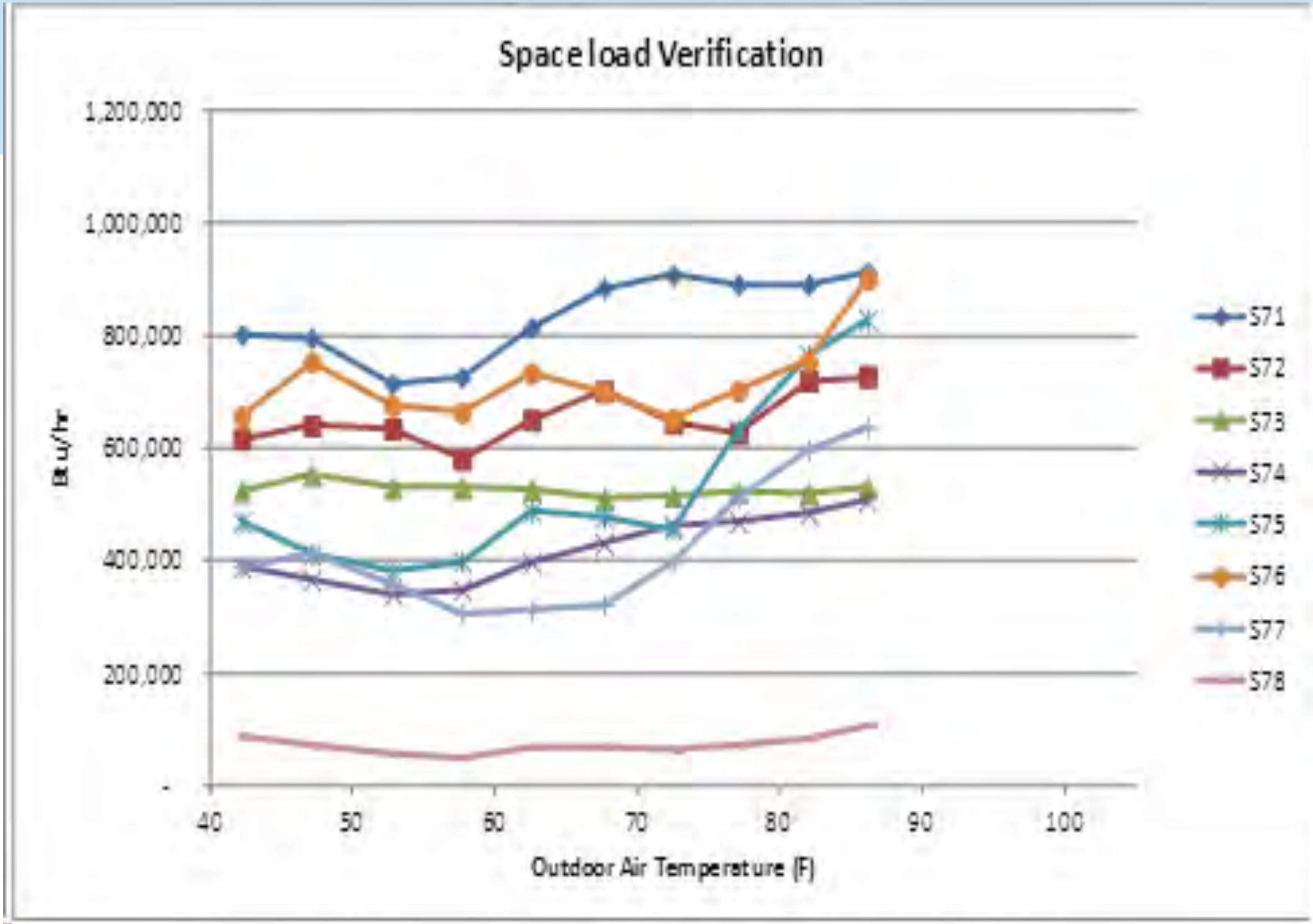
Implementation cost

- $3,500

Simple payback less than 0.15 years

Where did all the heat go?

- Even with over pumping and higher supply temperature, the energy needs to be absorbed somewhere.



- Estimate sensible energy for each AHU system
  - 1.08 x CFM x delta T
  - Assume AHU airflow is proportional to supply fan speed
  - Use supply air temperature and return air temperature delta T

Steam Systems

Get familiar with the system

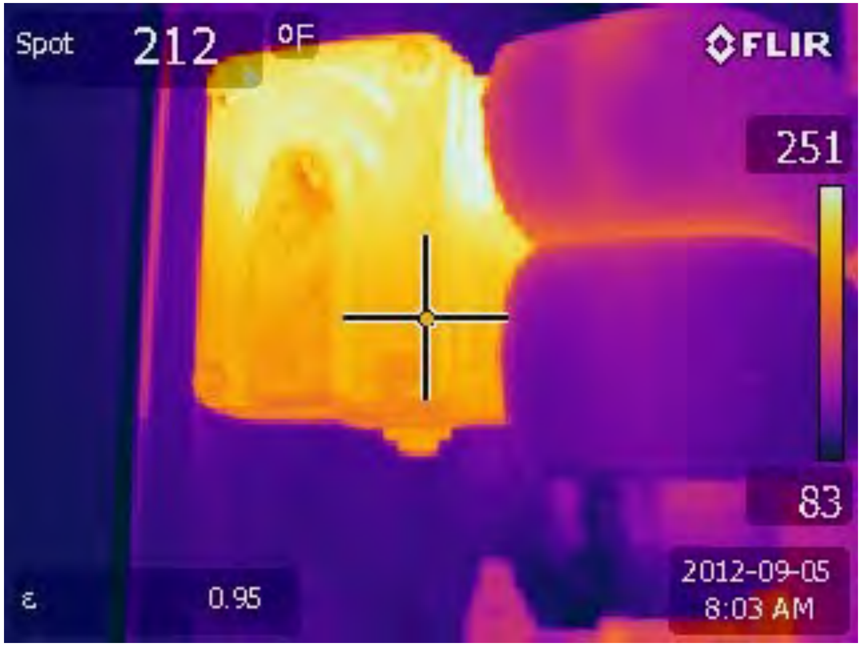
- What is the boiler steam pressure?
- What steam pressure is required by different components of the system?
- What is the typical steam load?
  - How many boilers are normally operated?
- Review utility data to compare winter and summer heating load.

Steam Systems

Potential Energy Savings Measures

- Failed steam traps
- Control valve failure or leakby
- Pipe insulation
- Simultaneous heating and cooling
- Boiler burner retrofit
- Repair steam leaks
- Return condensate to boiler
- Boiler blowdown heat recovery
- Stack economizer

Steam Trap Survey

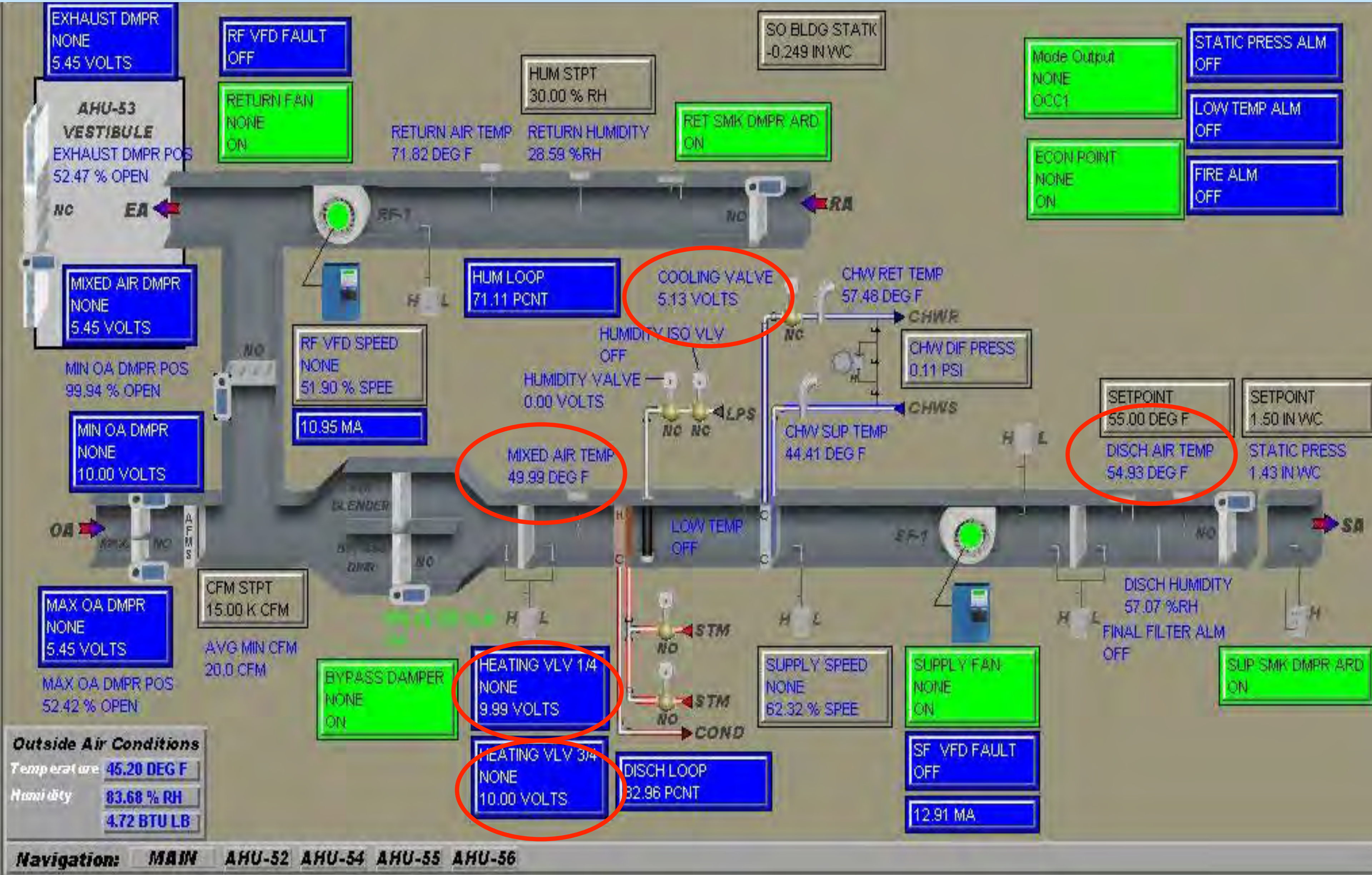


Steam Systems

Things to consider for typical ECMs

- **Pipe Insulation**
  - Is the pipe located in a conditioned space?
- **Is steam available all year?**

Steam System Example



Failed Steam Valves

- **Issue discovered on the BAS**
- **Investigate in the field to confirm and record field data.**
  - Measure heating coil surface temperature
  - Measure air temperature before and after heating coil.
  - Measure air temperature before and after cooling coil.
  - Manually isolate steam heating coil

Failed Steam Valves

Baseline: Steam valves are failed open.

- Install data loggers to monitor air temperature downstream of heating coil
- Trend steam and chilled water valve command value.

Implemented: Steam valves modulate to maintain DAT setpoint.

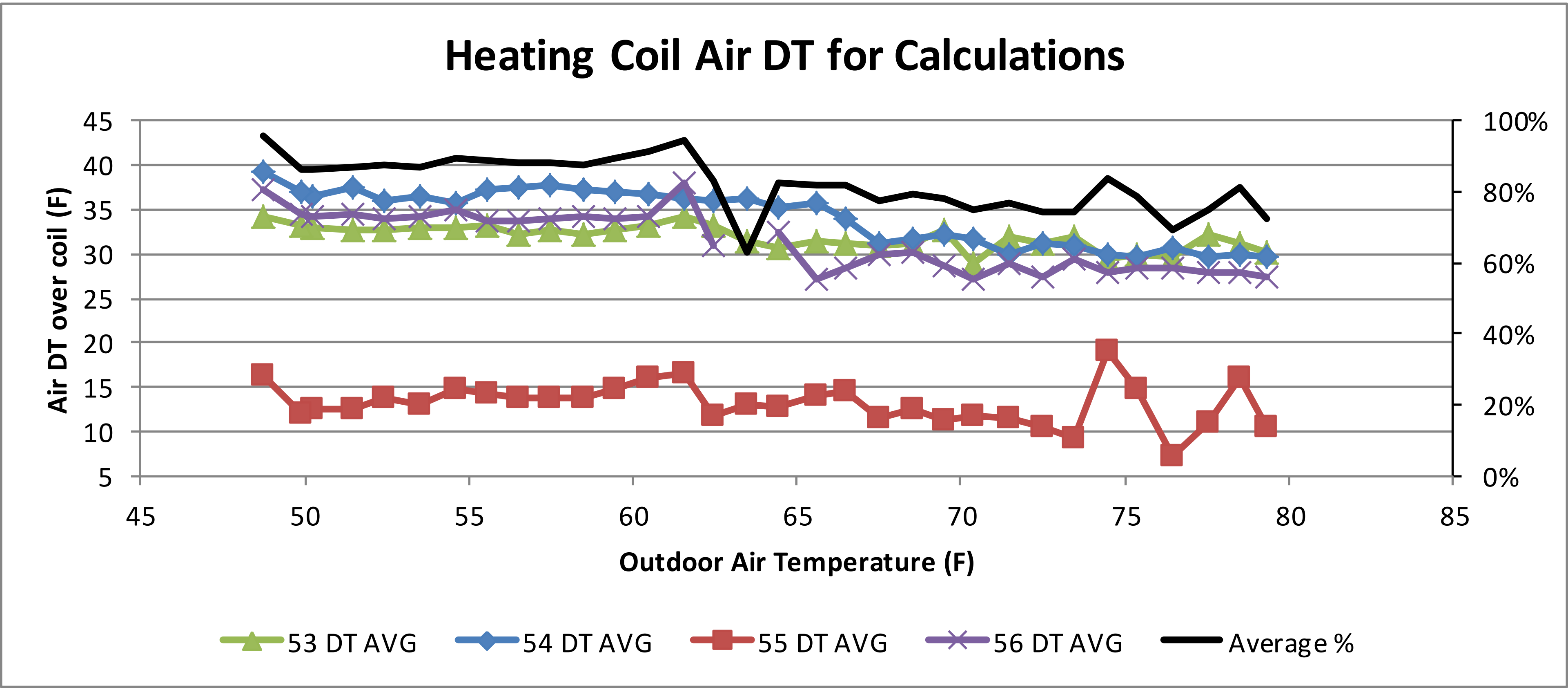
- Review trend data

Steam valve position is constant, is heat transfer constant?

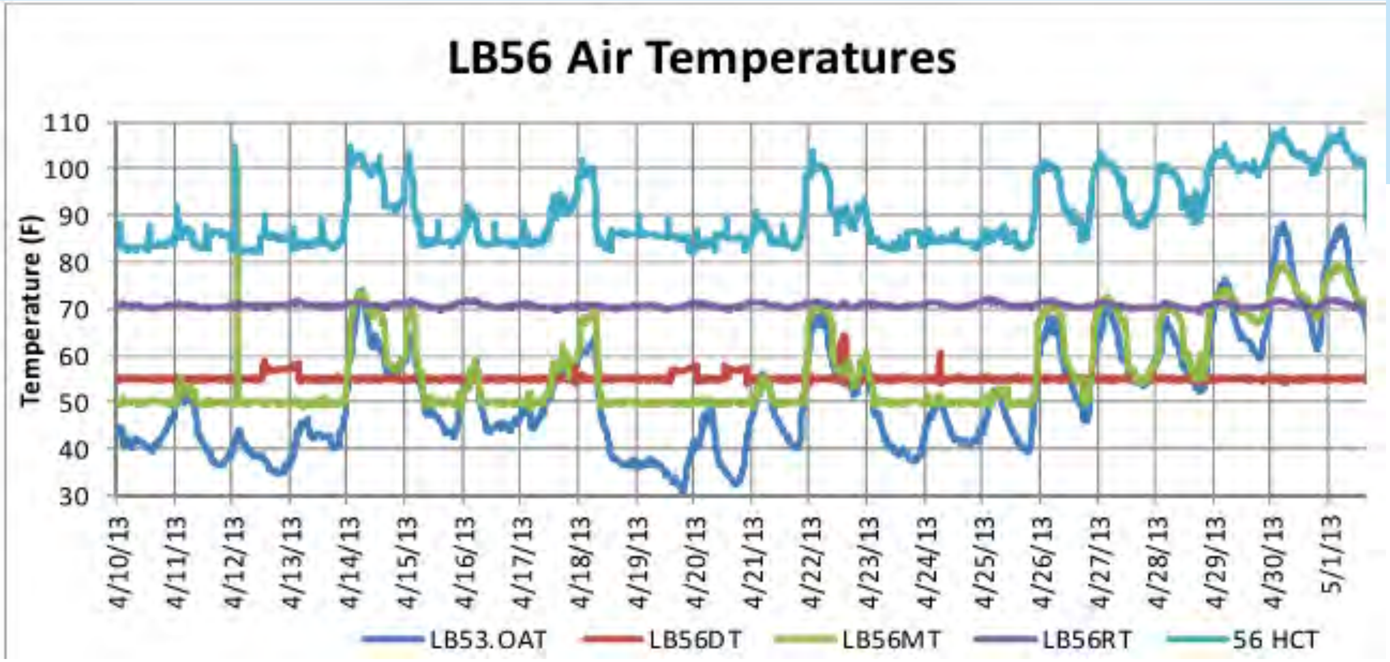
Failed Steam Valves

Heat transfer decreases as air temperature increases.

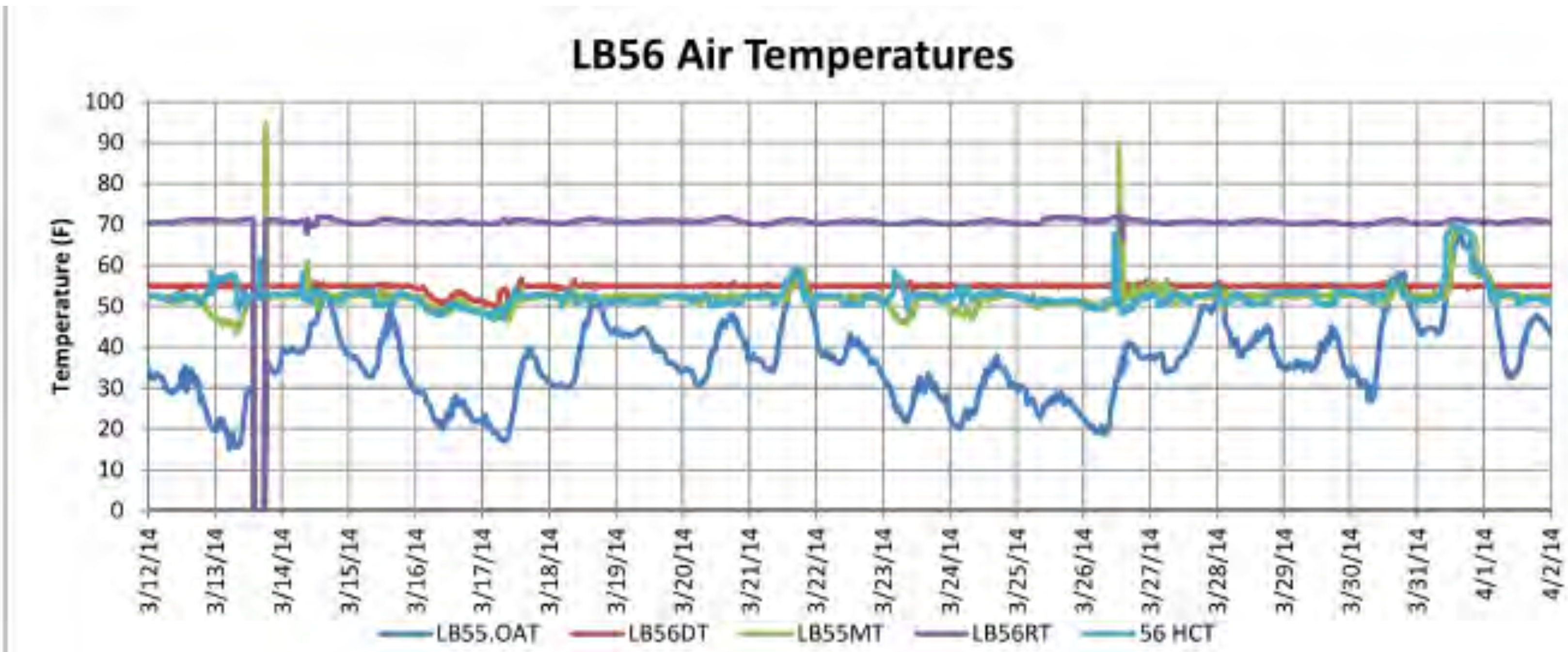
Normalize trend data and apply to energy savings calculations.



Baseline



Verified



Failed Steam Valves Example

Measure included 14 AHUs. Energy savings varied for each AHU.

Estimated annual savings for all AHUs

- 446,000 therms
- 1,800,000 kWh
- $315,000

Implementation cost

- $27,000

Simple payback less than 0.1 years.

Questions?

Thank you!

Fiona Martin, P.E., QCxP, BEAP, LEED AP O&M

fmartin@grummanbutkus.com

Tim Shinnick, P.E., QCxP, LEED AP

tshinnick@grummanbutkus.com

Grumman/Butkus Associates

Energy Consultants

Design Engineers

ASHRAE

Illinois Chapter