Center for Energy and Environment

ASHRAE December Chapter Meeting

Energy Saving Calculations for Recommissioning and Design

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December 13, 2011

Agenda

- Introduction
  - Trending and Trend Data
  - TMY and Bin Data
- AHU Measure
  - Optimize Airside Economizer
- Pump Measure
  - Install VFD on Hot Water Pump
- Wrap-up
- Questions

Recommissioning and Design

- Our background is RCx
- Differences
  - Existing vs New Buildings
  - Equipment-specific Calculations vs Whole Building Energy Modeling
  - Known Equipment Operation vs Design Criteria
- Common Goals
  - Comfortable and Safe Occupants
  - Low Energy Use
  - Easy to Maintain

  = High Performance Building

Source: www.wbdg.org

Top Energy Saving Measures in RCx

Key Measure Mix	% of Total Savings
Revise control sequence	21%
Reduce equipment runtime	15%
☆ Optimize airside economizer	12%
Add/optimize SAT reset	8%
☆ Add VFD to pump	6%
Reduce coil leakage	4%
Reduce/reset DSP setpoint	4%
Add/optimize optimum start/stop	3%
Add/optimize CWST reset	2%

Source: A Study on Energy Savings and Measure Cost Effectiveness of EBCx, PECI, 2009

Importance of Spreadsheet Calculations in Recommissioning (RCx) and Design

- Customizable for any application
- Can be based on actual building operation
- Applicable to multiple scenarios with little modification
- Most 3rd party tools apply to specific scenarios
  - "Square peg in round hole" syndrome
  - All inputs must be re-entered for each case
- Energy modeling is not economical for analysis of individual equipment
  - Time-consuming
  - Not intent of modeling software

Trending and Trend Data

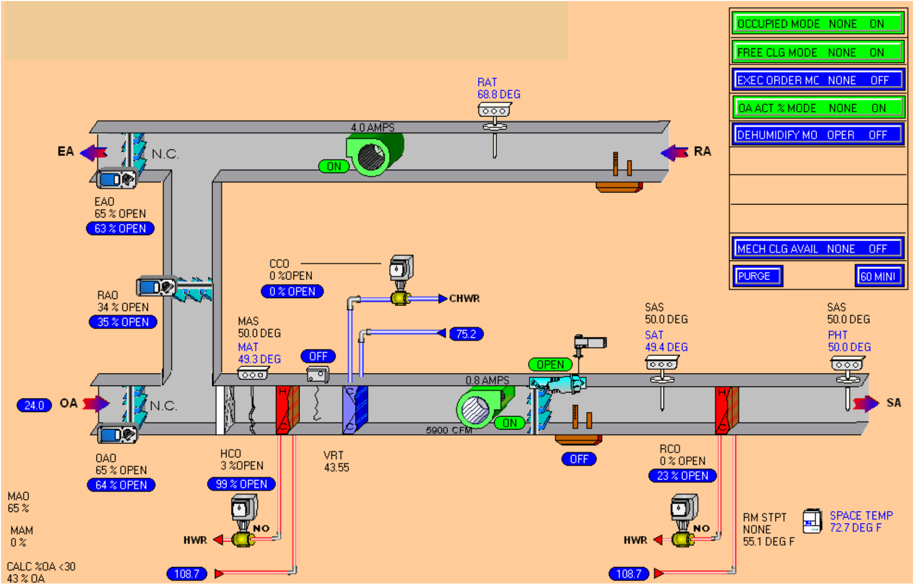
Trending- brief overview

- The process of capturing time series data on equipment operation
- Building Automation Systems (BAS) or data loggers
- Data is exported from the BAS or loggers for spreadsheet analysis
- Data set-up, collection, processing, and analysis are time consuming

Trending and Trend Data

Trend Data

- Time series data exported from BAS or data loggers
- 15 minute interval
- 6 continuous months minimum
  - Weather-dependency
  - Modes of operation
- Typical AHU has 15 channels
- Typical buildings have 300-500 channels
- 5-8 million data points



	OAT	SF-S	SF-Speed	DSP Stpt	DSP	RAT	OA Damper	MAT	DAT	DAT-SP	CLG VLV	HTG VLV	Radiation
8/4/2011 4:00	64.4	0	0.0	0.0	0.8	76.5	0.0	70.1	75.2	60.0	0.0	0	0.0
8/4/2011 4:15	63.9	0	0.0	0.0	0.8	76.3	0.0	70.1	75.1	60.0	0.0	0	0.0
8/4/2011 4:30	63.7	0	0.0	0.0	0.8	76.3	0.0	70.1	75.1	60.0	0.0	0	0.0
8/4/2011 4:45	63.9	0	0.0	0.0	0.8	76.3	0.0	70.2	75.1	60.0	0.0	0	0.0
8/4/2011 5:00	63.5	0	0.0	0.0	0.8	76.3	0.0	70.2	75.0	60.0	0.0	0	0.0
8/4/2011 5:15	63.3	0	0.0	0.0	0.8	75.9	0.0	68.6	75.7	60.0	0.0	0	0.0
8/4/2011 5:30	63.3	1	67.6	0.7	0.8	73.9	15.6	71.2	72.5	60.0	53.2	0	15.6
8/4/2011 5:45	63.3	1	70.2	0.8	0.8	73.8	15.7	71.1	73.5	60.0	100.0	0	15.7
8/4/2011 6:00	63.3	1	70.8	0.8	0.8	73.9	21.2	71.3	74.3	60.0	100.0	0	21.2
8/4/2011 6:15	63.4	1	71.4	0.8	0.8	73.9	19.5	71.3	74.4	60.0	100.0	0	19.5
8/4/2011 6:30	63.8	1	71.8	0.8	0.8	74.0	17.8	71.5	74.7	60.0	100.0	0	17.8
8/4/2011 6:45	64.4	1	72.1	0.8	0.8	74.1	18.3	71.6	74.8	60.0	100.0	0	18.3
8/4/2011 7:00	65.4	1	72.6	0.8	0.8	74.3	18.7	71.8	74.9	60.0	100.0	0	18.7
8/4/2011 7:15	66.9	1	72.6	0.8	0.8	73.8	14.8	71.3	60.0	60.0	98.6	0	14.8
8/4/2011 7:30	69.0	1	73.7	0.8	0.8	72.6	17.2	70.3	57.3	60.0	57.4	0	17.2
8/4/2011 7:45	70.6	1	74.3	0.8	0.8	71.8	13.7	69.8	59.6	60.0	32.3	0	13.7
8/4/2011 8:00	71.6	1	73.8	0.8	0.8	71.4	17.3	69.6	60.0	60.0	30.8	0	17.3
8/4/2011 8:15	72.6	1	73.1	0.8	0.8	71.3	15.5	69.4	59.9	60.0	30.0	0	15.5
8/4/2011 8:30	73.6	1	72.2	0.8	0.8	71.2	17.8	69.3	60.0	60.0	30.0	0	17.8
8/4/2011 8:45	74.9	1	72.3	0.8	0.8	71.1	12.6	69.2	60.1	60.0	30.0	0	12.6
8/4/2011 9:00	76.0	1	72.1	0.8	0.8	70.9	15.4	69.2	60.1	60.0	33.3	0	15.4
8/4/2011 9:15	78.0	1	72.1	0.8	0.8	70.8	18.6	69.2	60.3	60.0	37.6	0	18.6
8/4/2011 9:30	78.8	1	72.3	0.8	0.8	70.8	15.7	69.3	60.0	60.0	37.9	0	15.7
8/4/2011 9:45	79.2	1	72.2	0.8	0.8	70.8	17.0	69.2	59.8	60.0	37.3	0	17.0
8/4/2011 10:00	79.3	1	72.1	0.8	0.8	70.7	15.6	69.3	59.9	60.0	34.9	0	15.6
8/4/2011 10:15	80.4	1	72.1	0.8	0.8	70.6	14.5	69.3	59.9	60.0	32.9	0	14.5
8/4/2011 10:30	80.9	1	72.3	0.8	0.8	70.7	12.6	69.3	60.0	60.0	31.7	0	12.6
8/4/2011 10:45	80.6	1	72.0	0.8	0.8	70.7	15.9	69.4	59.9	60.0	31.1	0	15.9
8/4/2011 11:00	80.9	1	72.1	0.8	0.8	70.8	16.2	69.6	60.1	60.0	31.5	0	16.2
8/4/2011 11:15	81.6	1	72.3	0.8	0.8	70.9	17.6	69.6	60.0	60.0	32.2	0	17.6
8/4/2011 11:30	81.7	1	72.1	0.8	0.8	70.9	15.1	69.8	60.1	60.0	34.1	0	15.1
8/4/2011 11:45	82.0	1	71.9	0.8	0.8	71.1	18.1	69.9	60.4	60.0	39.7	0	18.1
8/4/2011 12:00	83.0	1	72.3	0.8	0.8	71.1	15.1	70.1	60.1	60.0	41.2	0	15.1


AHU-8 Operation
100
90
80
70
60
50
40
30
20
10
0
Temp (F) / Speed (%) / %Open (%)
4/8 0:00
4/8 2:00
4/8 4:00
4/8 6:00
4/8 8:00
4/8 10:00
4/8 12:00
4/8 14:00
4/8 16:00
4/8 18:00
4/8 20:00
4/8 22:00
5/8 0:00
Date / Time
SF-Speed
RAT
MAT
DAT
OA Damper
CLG VLV
HTG VLV
OAT

Trending and Trend Data

Why So Much Trending?

- Trend data allows you to identify operational issues you wouldn't find otherwise.
  - Unoccupied operation
  - Leaky valves, stuck dampers, etc
  - Suboptimal controls sequences
- Trend data allows you to more accurately calculate savings
- Once it is setup it keeps running
- You can never tell the weather what to do

TMY and Bin Data

- Typical Meteorological Year Weather Data
  - Covers at least 15 year timeframe
    - Average and typical, not average
  - "Major" Cities only
    - Duluth
    - International Falls
    - Minneapolis
    - Rochester
    - St Cloud
    - Fargo, ND
    - Sioux Falls, SD
  - 8,760 hours of data
    - Date/Time, Dry Bulb, Wet Bulb, Pressure, etc.
  - Get from NREL
    - http://www.nrel.gov/rredc/solar_data.html

TMY and Bin Data

Bin Data

- Data calculated in 5 F (or smaller) bins.
  - Split on setpoints
  - Size depending on sensitivity
- Best for equipment operation that is dependent on outside temperature
  - Can also be done for Enthalpy, Wetbulb, etc.

TMY and Bin Data

Bin Data

- Calculate using AVERAGEIFS() and COUNTIFS()
- AVERRAGEIFS() - Average value of a range, given criteria
- COUNTIFS() - Number of occurrences in a range, given criteria

OAT Bins		Avg OAT (F)	Hours	Hours ON
60	65	63.7	3	1.5
65	70	68.5	2.25	0.75
70	75	72.4	3.25	1.25
75	80	77.8	2	1.25
80	85	82.5	8.25	5.75
85	90	85.8	1.25	1.25

=AVERAGEIFS(Avg Range, CriteriaRange1, Criteria1, CriteriaRange2,Criteria2, …)

=AVERAGEIFS(OAT Column, OAT Column,">="&BinLL, OAT Column,"<"&BinUL)

Agenda

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  - Trending and Trend Data
  - TMY and Bin Data
- AHU Measure
  - Optimize Airside Economizer
- Pump Measure
  - Install VFD on Hot Water Pump
- Wrap-up
- Questions and Comments

Optimize Airside Economizer

- Economizers malfunction frequently
  - Stuck outside damper, outside air (OA) flow station error, temperature/humidity sensor out of calibration, etc
- Economizer control errors
  - Incorrect high and/or low limit setpoint
- Result in a loss of "free cooling" opportunity, significant wasted cooling energy, or simultaneous heating and cooling

Optimize Airside Economizer

❖ Identification

- Look at BAS settings
- Functional performance testing
- Analyze trend data

❖ Required Trend Data

- SF Status and/or Speed
- Outside Air Temperature (OAT)
- Return Air Temperature (RAT)
- Mixed Air Temperature (MAT)
- OA damper position

Optimize Airside Economizer

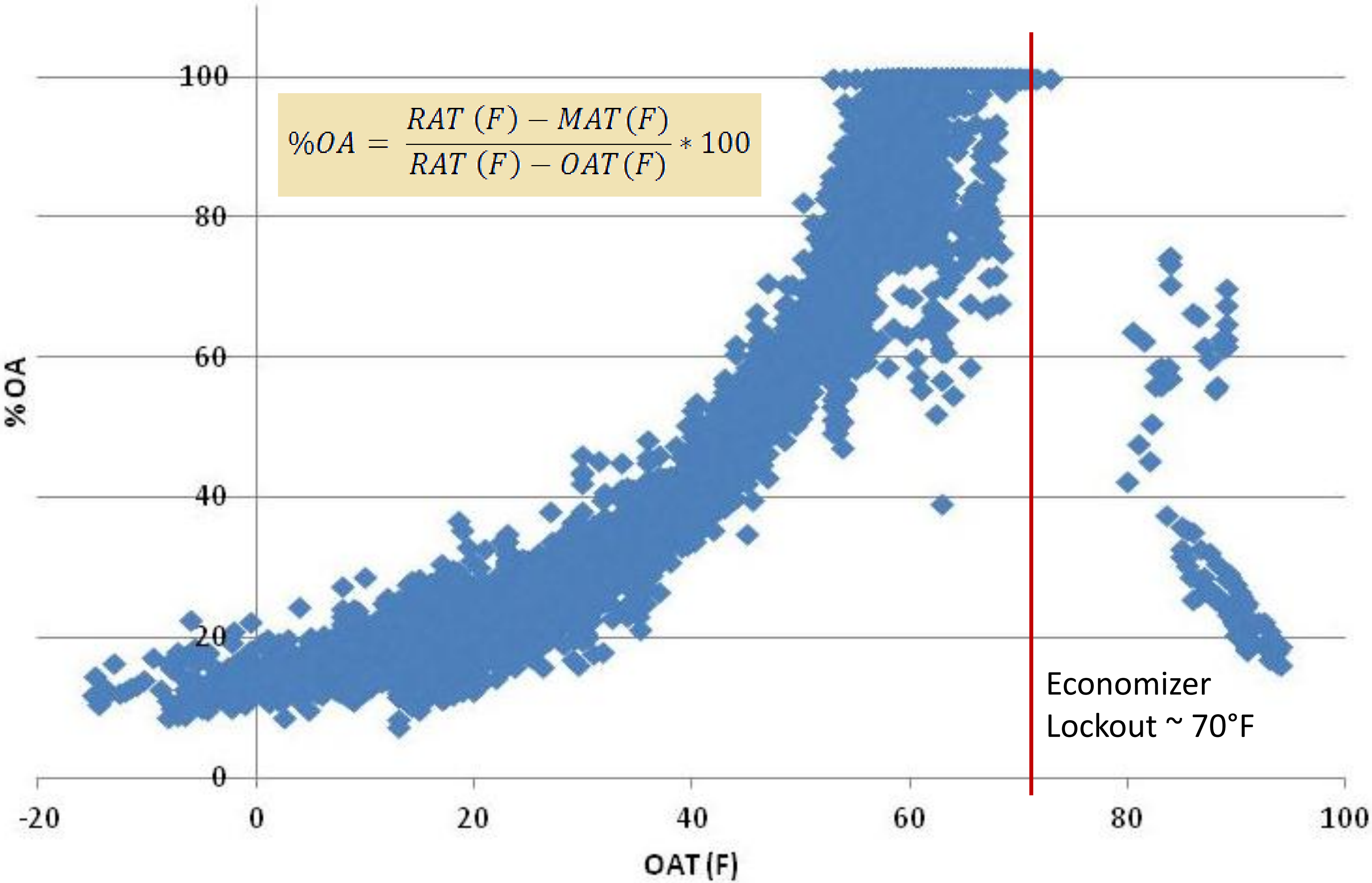
- Data Analysis
  - How much OA is the AHU bringing in?
    - Calculate the %OA

$$\%OA = \frac{RAT\,(F) - MAT\,(F)}{RAT\,(F) - OAT\,(F)} * 100$$

    - Plot %OA against OAT

%OA vs OAT - IDEAL PATTERN

$$\%OA = \frac{RAT\,(F) - MAT\,(F)}{RAT\,(F) - OAT\,(F)} * 100$$



Optimize Airside Economizer

- Why should the high limit setpoint be ~70 F?
  - Eliminates possible errors due to humidity sensors
    - Iowa Energy Center Research
    - http://www.energy.iastate.edu/Efficiency/Commercial/download_nbcip/NBCIP_S.pdf
  - High limit of 71 F in MN was found to be ideal
    - Taylor Engineering Research
    - November 2010 ASHRAE Journal (Vol. 52, No. 11)
  - The fewer control points the better

Optimize Airside Economizer

- Savings Calculation
  - Equation to determine OA flow

$$OA\ Flow\ (cfm) = \ OA\ (\%) * \ SF\ Flow\ (cfm)$$

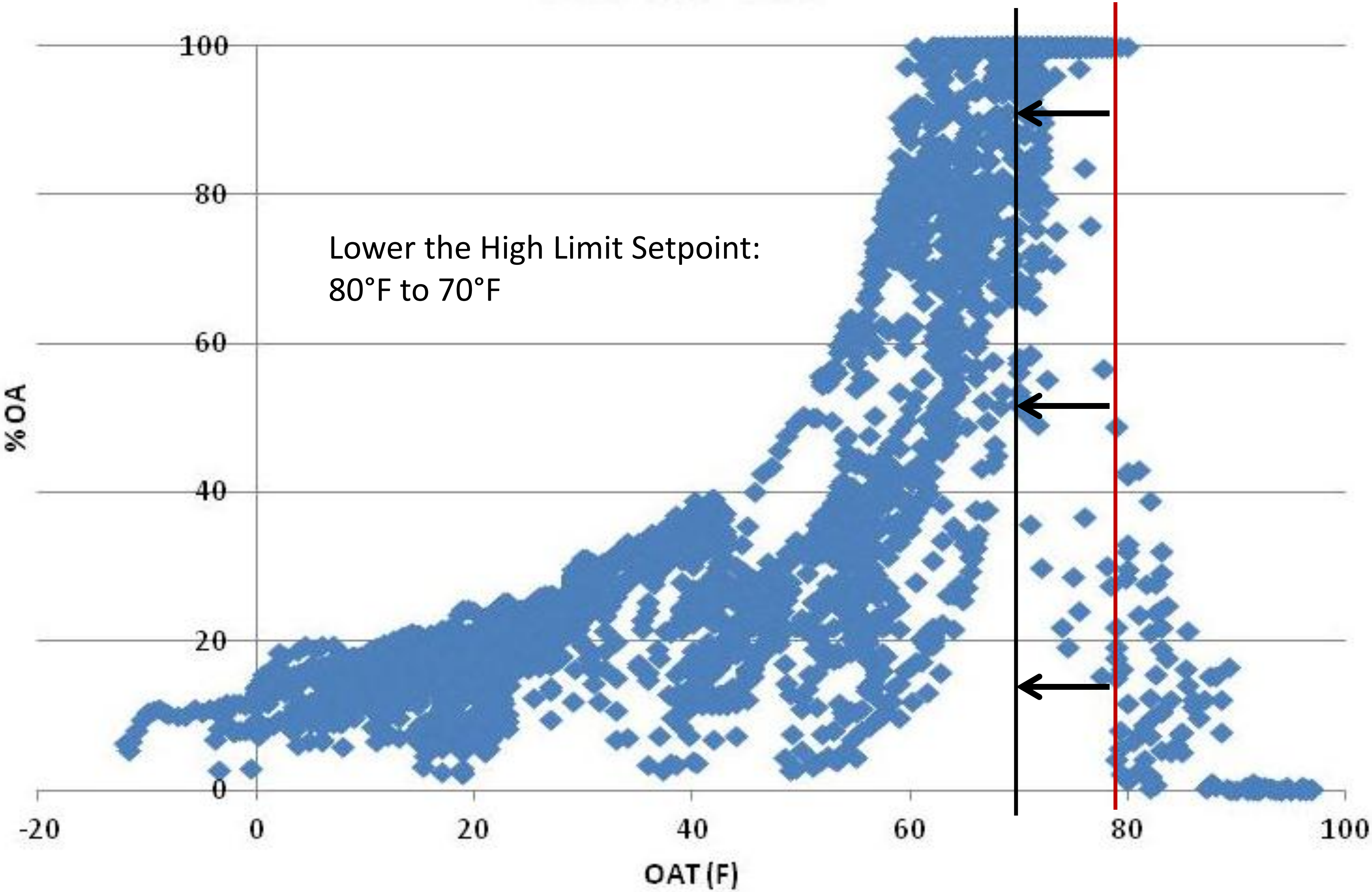
  - Equation to determine energy required to condition OA

$$Q\ (Btu) = \ 1.08 * OA\ Flow\ (cfm) * [RAT\ (F) - \ OAT\ (F)] * Hours$$

Optimize Airside Economizer Example

- Community College in North Metro
- 400,000 sqft
- 36 AHUs- mix of multi-zone, VAV, and constant volume
  - This example- 14,500 cfm constant volume AHU
- 809 channels were trended, 25.3M total data points collected over 10 months
- Finding (problem)
  - Economizer high limit lockout is 80 F
- Measure (solution)
  - Change the lockout to 70 F

%OA vs OAT - HIGH LIMIT TOO HIGH



Optimize Airside Economizer Example

❖ Spreadsheet Calculation Layout

- Reducing the high limit setpoint will lead to savings whenever 70 F < OAT < 80 F

1				2				3				
A	B	C	D	E	F	G	H	I	J	K	L	
				Current				Proposed				
OAT Dry Bulb Bin	OAT Dry Bulb	AHU On	RAT	OA	OA Flow	OA Cooling Energy	OA Cooling Input	OA	OA Flow	OA Cooling Energy	OA Cooling Input	Savings
F	F	Hours	F	%	CFM	kBtus	kWh	%	CFM	kBtus	kWh	kWh
60/64	62.6	321	70.8	67.9%	9,840	0	0	67.9%	9,840	0	0	0
65/69	68.1	294	71.2	87.7%	12,712	0	0	87.7%	12,712	0	0	0
70/74	72.5	265	71.6	95.5%	13,847	3,400	340	10.0%	1,450	356	36	304
75/79	76.9	317	71.6	78.0%	11,307	20,534	2,053	10.0%	1,450	2,633	263	1790
80/84	82.1	284	72.6	18.2%	2,643	7,688	769	10.0%	1,450	4,218	422	347
85/89	87.8	152	72.0	10.0%	1,450	3,758	376	10.0%	1,450	3,758	376	0
90/94	91.9	54	73.0	10.0%	1,450	1,594	159	10.0%	1,450	1,594	159	0
												2,442

Optimize Airside Economizer Example

1

A	B	C	D
OAT Dry Bulb Bin	**OAT Dry Bulb**	**AHU On**	**RAT**
F	**F**	**Hours**	**F**
60/64	62.6	321	70.8
65/69	68.1	294	71.2
70/74	72.5	265	71.6
75/79	76.9	317	71.6
80/84	82.1	284	72.6
85/89	87.8	152	72.0
90/94	91.9	54	73.0

Column A- OAT Bins

- 5 F Bins

Column B- Average OAT for Bin

- Obtain from TMY Data
- Use AVERAGEIFS

Column C- Total Hours the AHU operates during Bin

- Obtain from trends of SF Status or Speed and OAT
- Use COUNTIFS

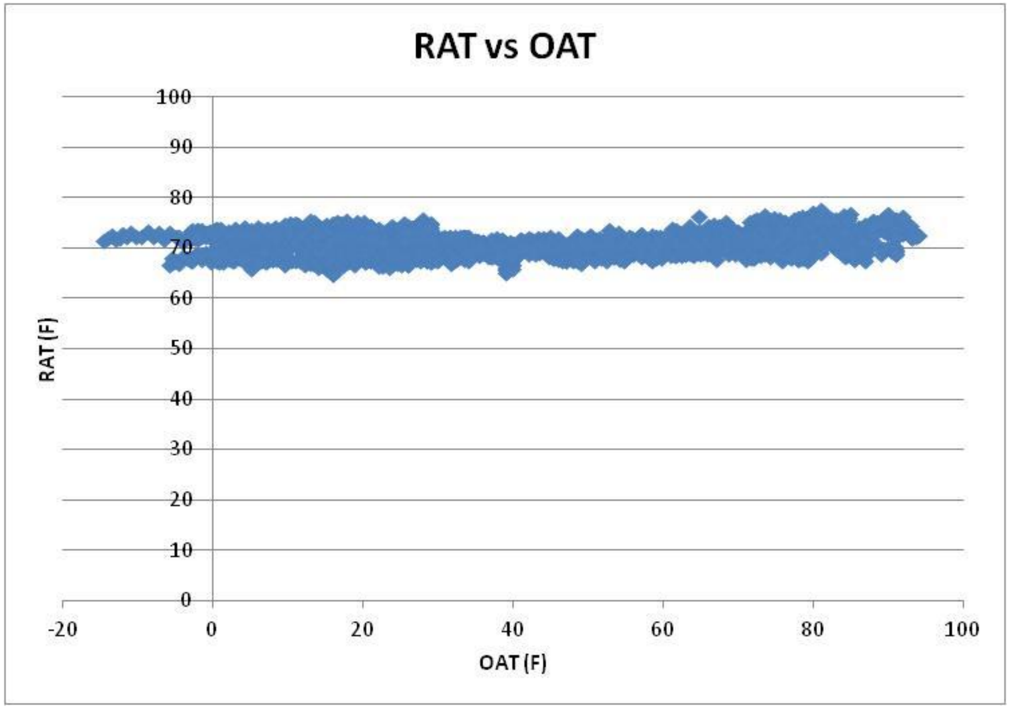
Optimize Airside Economizer Example

1

A	B	C	D
OAT Dry Bulb Bin	OAT Dry Bulb	AHU On	RAT
F	F	Hours	F
60/64	62.6	321	70.8
65/69	68.1	294	71.2
70/74	72.5	265	71.6
75/79	76.9	317	71.6
80/84	82.1	284	72.6
85/89	87.8	152	72.0
90/94	91.9	54	73.0

Column D- Average RAT during Bin

- Obtain from trends of RAT and OAT
- Plot RAT vs OAT to see overall pattern
- Use AVERAGEIFS- Filter for when AHU is ON



Optimize Airside Economizer Example

- Spreadsheet Calculation Layout

1				2				3				
A	B	C	D	E	F	G	H	I	J	K	L	
				Current				Proposed				
OAT Dry Bulb Bin	OAT Dry Bulb	AHU On	RAT	OA	OA Flow	OA Cooling Energy	OA Cooling Input	OA	OA Flow	OA Cooling Energy	OA Cooling Input	Savings
F	F	Hours	F	%	CFM	kBtus	kWh	%	CFM	kBtus	kWh	kWh
60/64	62.6	321	70.8	67.9%	9,840	0	0	67.9%	9,840	0	0	0
65/69	68.1	294	71.2	87.7%	12,712	0	0	87.7%	12,712	0	0	0
70/74	72.5	265	71.6	95.5%	13,847	3,400	340	10.0%	1,450	356	36	304
75/79	76.9	317	71.6	78.0%	11,307	20,534	2,053	10.0%	1,450	2,633	263	1790
80/84	82.1	284	72.6	18.2%	2,643	7,688	769	10.0%	1,450	4,218	422	347
85/89	87.8	152	72.0	10.0%	1,450	3,758	376	10.0%	1,450	3,758	376	0
90/94	91.9	54	73.0	10.0%	1,450	1,594	159	10.0%	1,450	1,594	159	0
												2,442

Optimize Airside Economizer Example

2

A	E	F	G	H
OAT Dry Bulb Bin		Current		
	OA	OA Flow	OA Cooling Energy	OA Cooling Input
F	%	CFM	kBtus	kWh
60/64	67.9%	9,840	0	0
65/69	87.7%	12,712	0	0
70/74	95.5%	13,847	3,400	340
75/79	78.0%	11,307	20,534	2,053
80/84	18.2%	2,643	7,688	769
85/89	10.0%	1,450	3,758	376
90/94	10.0%	1,450	1,594	159

Column E- Average %OA during Bin

- Obtain from trends of MAT, RAT, and OAT
- Plot %OA vs OAT to see overall pattern
- Use AVERAGEIFS- Filter for when AHU is ON

$$\%OA = \frac{RAT\,(F) - MAT\,(F)}{RAT\,(F) - OAT\,(F)} * 100$$

Optimize Airside Economizer Example

2

A	E	F	G	H
		Current		
OAT Dry Bulb Bin	OA	OA Flow	OA Cooling Energy	OA Cooling Input
F	%	CFM	kBtus	kWh
60/64	67.9%	9,840	0	0
65/69	87.7%	12,712	0	0
70/74	95.5%	13,847	3,400	340
75/79	78.0%	11,307	20,534	2,053
80/84	18.2%	2,643	7,688	769
85/89	10.0%	1,450	3,758	376
90/94	10.0%	1,450	1,594	159

Column F- OA Flow

- Calculated using equation below
- SF Speed must be accounted for with variable volume AHUs

Column G- Cooling Energy

- Energy required to cool OA
- Calculated using equation below

$$OA\ Flow\ (cfm) = OA\ (\%) * SF\ Flow\ (cfm)$$

$$Q\ (Btu) = 1.08 * OA\ Flow\ (cfm) * [RAT\ (F) - OAT\ (F)] * Hours$$

Optimize Airside Economizer Example

2

A	E	F	G	H
	Current			
OAT Dry Bulb Bin	**OA**	**OA Flow**	**OA Cooling Energy**	**OA Cooling Input**
F	**%**	**CFM**	**kBtus**	**kWh**
60/64	67.9%	9,840	0	0
65/69	87.7%	12,712	0	0
70/74	95.5%	13,847	3,400	340
75/79	78.0%	11,307	20,534	2,053
80/84	18.2%	2,643	7,688	769
85/89	10.0%	1,450	3,758	376
90/94	10.0%	1,450	1,594	159

Column H- Cooling Input

- Calculated using equation below

$$Q\ (kWh) = \frac{Q\ (kBtu) * \ Chiller\ Efficiency\ (kW/Ton)}{12}$$

Optimize Airside Economizer Example

- Spreadsheet Calculation Layout

1				2				3				
A	B	C	D	E	F	G	H	I	J	K	L	
				Current				Proposed				
OAT Dry Bulb Bin	OAT Dry Bulb	AHU On	RAT	OA	OA Flow	OA Cooling Energy	OA Cooling Input	OA	OA Flow	OA Cooling Energy	OA Cooling Input	Savings
F	F	Hours	F	%	CFM	kBtus	kWh	%	CFM	kBtus	kWh	kWh
60/64	62.6	321	70.8	67.9%	9,840	0	0	67.9%	9,840	0	0	0
65/69	68.1	294	71.2	87.7%	12,712	0	0	87.7%	12,712	0	0	0
70/74	72.5	265	71.6	95.5%	13,847	3,400	340	10.0%	1,450	356	36	304
75/79	76.9	317	71.6	78.0%	11,307	20,534	2,053	10.0%	1,450	2,633	263	1790
80/84	82.1	284	72.6	18.2%	2,643	7,688	769	10.0%	1,450	4,218	422	347
85/89	87.8	152	72.0	10.0%	1,450	3,758	376	10.0%	1,450	3,758	376	0
90/94	91.9	54	73.0	10.0%	1,450	1,594	159	10.0%	1,450	1,594	159	0
												2,442

Optimize Airside Economizer Example

3

A	I	J	K	L
OAT Dry Bulb Bin	**Proposed**			
	OA	**OA Flow**	**OA Cooling Energy**	**OA Cooling Input**
F	**%**	**CFM**	**kBtus**	**kWh**
60/64	67.9%	9,840	0	0
65/69	87.7%	12,712	0	0
70/74	10.0%	1,450	356	36
75/79	10.0%	1,450	2,633	263
80/84	10.0%	1,450	4,218	422
85/89	10.0%	1,450	3,758	376
90/94	10.0%	1,450	1,594	159

Columns I thru L

- Repeat the same analysis for Proposed Scenario
- Above 70 F, the %OA will drop to minimum position
- Based on data at low OATs, the minimum %OA is 10%

Optimize Airside Economizer Example

A	B	C	D	E	F	G	H	I	J	K	L	
				Current				Proposed				
OAT Dry Bulb Bin	OAT Dry Bulb	AHU On	RAT	OA	OA Flow	OA Cooling Energy	OA Cooling Input	OA	OA Flow	OA Cooling Energy	OA Cooling Input	Savings
F	F	Hours	F	%	CFM	kBtus	kWh	%	CFM	kBtus	kWh	kWh
60/64	62.6	321	70.8	67.9%	9,840	0	0	67.9%	9,840	0	0	0
65/69	68.1	294	71.2	87.7%	12,712	0	0	87.7%	12,712	0	0	0
70/74	72.5	265	71.6	95.5%	13,847	3,400	340	10.0%	1,450	356	36	304
75/79	76.9	317	71.6	78.0%	11,307	20,534	2,053	10.0%	1,450	2,633	263	1790
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85/89	87.8	152	72.0	10.0%	1,450	3,758	376	10.0%	1,450	3,758	376	0
90/94	91.9	54	73.0	10.0%	1,450	1,594	159	10.0%	1,450	1,594	159	0
												2,442

- Savings
  - 2,442 kWh annually or $170 at 7¢/kWh
  - ~10% of energy used to cool OA
  - No cost to implement

Optimize Airside Economizer

Summary of Measure

- Keep in mind that….
  - An AHU may economize at OATs as low as 20 or 30 F
  - Humidity sensors have a tendency to get out of calibration
  - The fewer sensors the economizer relies on, the better
- Design Implications
  - This analysis could be used to determine the savings from installing a unit with an economizer or a DOAS

Agenda

- Introduction
  - Trending and Trend Data
  - TMY and Bin Data
- AHU Measure
  - Optimize Airside Economizer
- Pump Measure
  - Install VFD on Hot Water Pump
- Wrap-up
- Questions

Install VFD on Hot Water Pump

- Constant volume pumping is common in existing buildings.
- Hot water loops come in many variants; primary, primary/secondary, primary/tertiary, etc.
- Energy savings from reducing the speed at which the pump run.
- Opportunities exist when the delta T is low and/or when the use in the AHUs are low.

Install VFD on Hot Water Pump

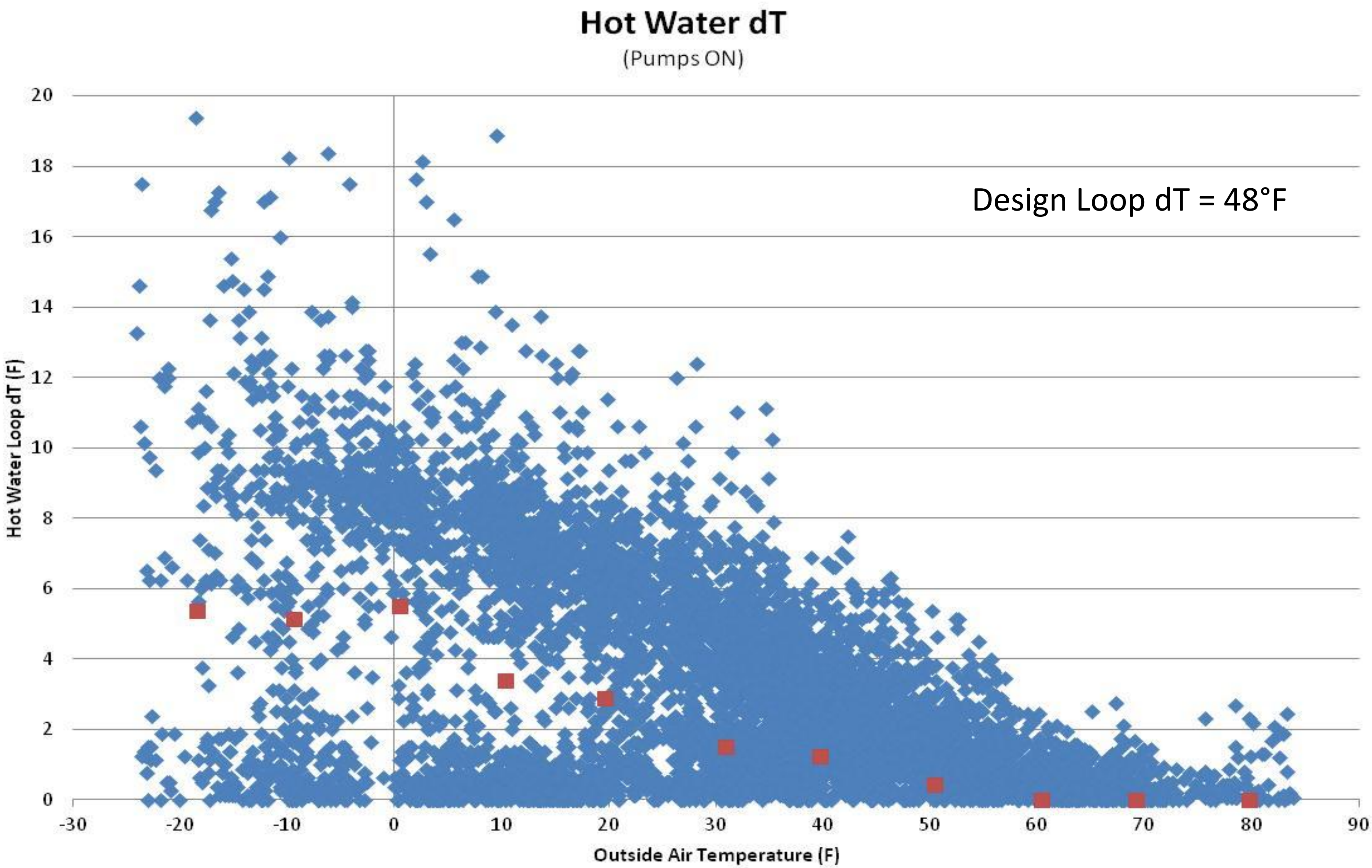
- Identification
  - Analyze trend data

- Required Trend Data
  - Pump Status
  - Boiler Status
  - Outside Air Temperature (OAT)
  - Supply Water Temperature (SHWS-T)
  - Return Water Temperature (SHWR-T)
  - AHU Heating Valve Positions

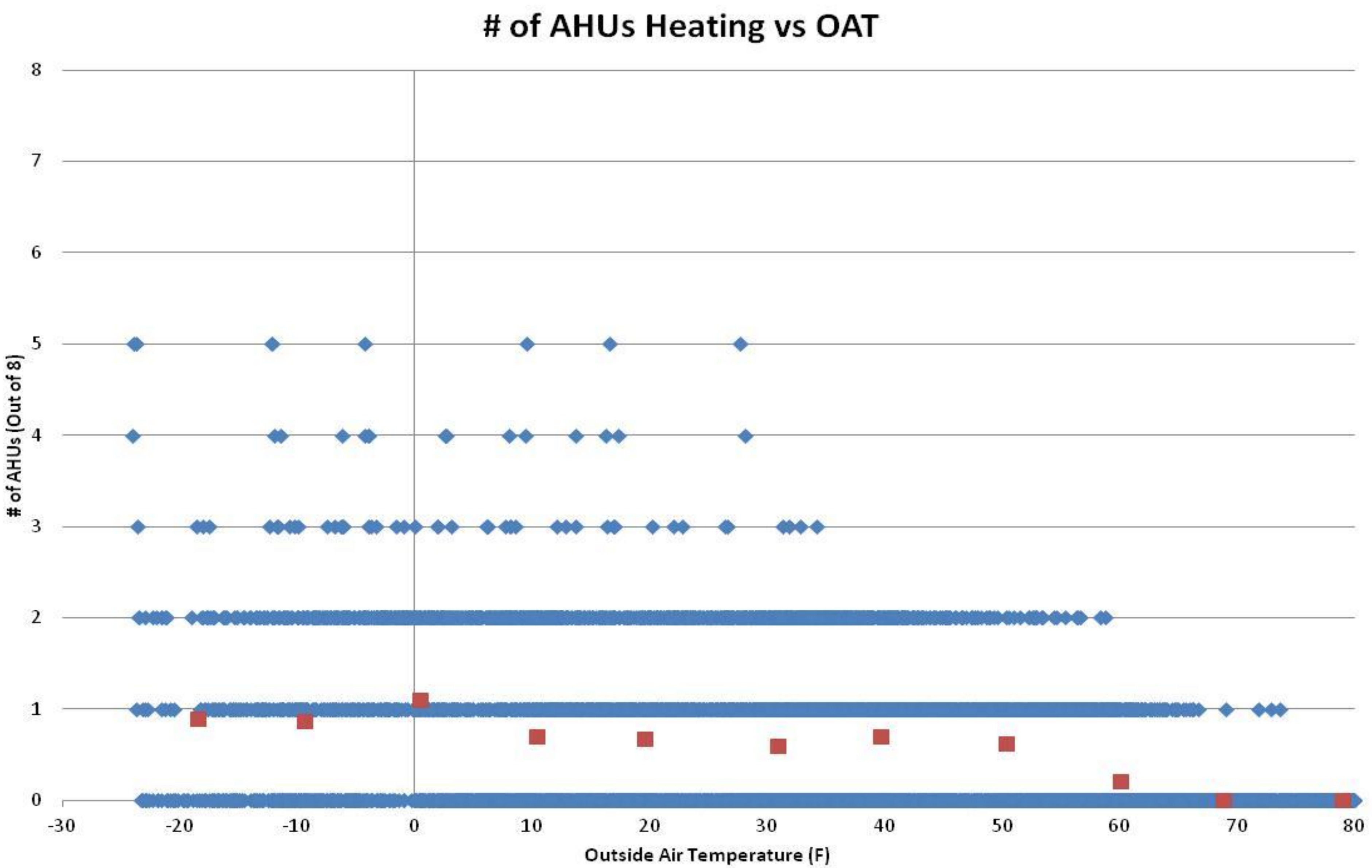
Install VFD on Hot Water Pump

- Data Analysis
  - How excessive is the pump operation?
    - When do the AHUs heat?
    - What is the loop differential temperature (dT)?

Example of low temperature drop



Example of Low use of heating at the AHUs



Install VFD on Hot Water Pump

Savings Calculation

- Equation to determine the flow at different OAT Bins
  - AVERAGEIFS for heating coils in each bin
  - AHU Coil Capacity from plans

$$\sum Avg.\,AHU\ Valve\ Pos * AHU\ Coil\ Flow$$

- Equation to determine pump power at different flow requirements
  - A power of 2 accounts for the motor and VFD efficiency and other losses.
  - More closely estimates the actual power, so energy savings are more accurate

$$Power_2 = Power_1 * \left(\frac{Speed_2}{Speed_1}\right)^2$$

Install VFD on Hot Water Pump

- Example
  - Middle School in Northwest Minnesota
  - 8 Large constant volume AHUs serving duct reheat coils with manual thermostats
  - 180 channels were trended, 3.3M total points collected over 7 months
  - Finding (problem)
    - Secondary Hot Water Loop Pump runs excessively
  - Measure (solution)
    - Install VFD on 40hp Pump, close off three way valves, and install differential pressure sensor

Install VFD on Hot Water Pump

❖ Calculation Layout

1

2

OAT Bin		Bin Hours	% of Total Flow								%Req. Flow (min 30%)	Energy Use	
			11.8%	11.3%	7.0%	13.1%	5.5%	15.6%	14.8%	20.9%		Current	Proposed
			AHU-1	AHU-2	AHU-3	AHU-4	AHU-5	AHU-6	AHU-7	AHU-8		(kWh)	(kWh)
-20	-10	248	100%	59%	100%	63%	58%	64%	89%	77%	76%	6,994	4,061
-10	0	309	100%	62%	100%	63%	60%	55%	73%	66%	70%	8,714	4,328
0	10	436	100%	68%	100%	54%	62%	52%	68%	48%	65%	12,295	5,226
10	20	696	100%	48%	100%	44%	45%	40%	48%	36%	53%	19,627	5,600
20	30	1074	100%	27%	100%	28%	27%	31%	27%	15%	39%	30,287	4,622
30	40	1224	100%	18%	100%	0%	10%	20%	3%	8%	30%	34,517	3,107
40	50	1114	100%	8%	100%	0%	3%	14%	0%	7%	30%	31,415	2,827
50	60	1135	100%	0%	100%	0%	0%	9%	0%	3%	30%	32,007	2,881
60	70	1157	0%	0%	0%	0%	0%	0%	0%	0%	30%	32,627	2,936
												208,483	**35,588**
												Savings	**172,895**

Install VFD on Hot Water Pump

- Part 1 – Finding %Flow in OAT Bins

OAT Bin		% of Total Flow								%Flow (min 30%)
		11.8%	11.3%	7.0%	13.1%	5.5%	15.6%	14.8%	20.9%	
		AHU-1	AHU-2	AHU-3	AHU-4	AHU-5	AHU-6	AHU-7	AHU-8	
-20	-10	100%	59%	100%	63%	58%	64%	89%	77%	76%
-10	0	100%	62%	100%	63%	60%	55%	73%	66%	70%
0	10	100%	68%	100%	54%	62%	52%	68%	48%	65%
10	20	100%	48%	100%	44%	45%	40%	48%	36%	53%
20	30	100%	27%	100%	28%	27%	31%	27%	15%	39%
30	40	100%	18%	100%	0%	10%	20%	3%	8%	30%
40	50	100%	8%	100%	0%	3%	14%	0%	7%	30%
50	60	100%	0%	100%	0%	0%	9%	0%	3%	30%
60	70	0%	0%	0%	0%	0%	0%	0%	0%	30%

Install VFD on Hot Water Pump

❖ AHU Heating Coil Capacities

1

OAT Bin		% of Total Flow								%Flow (min 30%)
		11.8%	11.3%	7.0%	13.1%	5.5%	15.6%	14.8%	20.9%	
		AHU-1	AHU-2	AHU-3	AHU-4	AHU-5	AHU-6	AHU-7	AHU-8	
-20	-10	100%	59%	100%	63%	58%	64%	89%	77%	76%
-10	0	100%	62%	100%	63%	60%	55%	73%	66%	70%
0	10	100%	68%	100%	54%	62%	52%	68%	48%	65%
10	20	100%	48%	100%	44%	45%	40%	48%	36%	53%
20	30	100%	27%	100%	28%	27%	31%	27%	15%	39%
30	40	100%	18%	100%	0%	10%	20%	3%	8%	30%
40	50	100%	8%	100%	0%	3%	14%	0%	7%	30%
50	60	100%	0%	100%	0%	0%	9%	0%	3%	30%
60	70	0%	0%	0%	0%	0%	0%	0%	0%	30%

Install VFD on Hot Water Pump

- AHU Heating Valve Average Position

1

OAT Bin		% of Total Flow								%Flow (min 30%)
		11.8%	11.3%	7.0%	13.1%	5.5%	15.6%	14.8%	20.9%	
		AHU-1	AHU-2	AHU-3	AHU-4	AHU-5	AHU-6	AHU-7	AHU-8	
-20	-10	100%	59%	100%	63%	58%	64%	89%	77%	76%
-10	0	100%	62%	100%	63%	60%	55%	73%	66%	70%
0	10	100%	68%	100%	54%	62%	52%	68%	48%	65%
10	20	100%	48%	100%	44%	45%	40%	48%	36%	53%
20	30	100%	27%	100%	28%	27%	31%	27%	15%	39%
30	40	100%	18%	100%	0%	10%	20%	3%	8%	30%
40	50	100%	8%	100%	0%	3%	14%	0%	7%	30%
50	60	100%	0%	100%	0%	0%	9%	0%	3%	30%
60	70	0%	0%	0%	0%	0%	0%	0%	0%	30%

Install VFD on Hot Water Pump

- %Flow calculated in Bins

1

$$\sum Avg.\,AHU\ Valve\ Pos * AHU\ Coil\ Flow$$

OAT Bin		% of Total Flow								%Flow (min 30%)
		11.8%	11.3%	7.0%	13.1%	5.5%	15.6%	14.8%	20.9%	
		AHU-1	AHU-2	AHU-3	AHU-4	AHU-5	AHU-6	AHU-7	AHU-8	
-20	-10	100%	59%	100%	63%	58%	64%	89%	77%	76%
-10	0	100%	62%	100%	63%	60%	55%	73%	66%	70%
0	10	100%	68%	100%	54%	62%	52%	68%	48%	65%
10	20	100%	48%	100%	44%	45%	40%	48%	36%	53%
20	30	100%	27%	100%	28%	27%	31%	27%	15%	39%
30	40	100%	18%	100%	0%	10%	20%	3%	8%	30%
40	50	100%	8%	100%	0%	3%	14%	0%	7%	30%
50	60	100%	0%	100%	0%	0%	9%	0%	3%	30%
60	70	0%	0%	0%	0%	0%	0%	0%	0%	30%

Install VFD on Hot Water Pump

❖ Calculation Layout

1

2

OAT Bin		Bin Hours	% of Total Flow								%Req. Flow (min 30%)	Energy Use	
			11.8%	11.3%	7.0%	13.1%	5.5%	15.6%	14.8%	20.9%		Current	Proposed
			AHU-1	AHU-2	AHU-3	AHU-4	AHU-5	AHU-6	AHU-7	AHU-8		(kWh)	(kWh)
-20	-10	248	100%	59%	100%	63%	58%	64%	89%	77%	76%	6,994	4,061
-10	0	309	100%	62%	100%	63%	60%	55%	73%	66%	70%	8,714	4,328
0	10	436	100%	68%	100%	54%	62%	52%	68%	48%	65%	12,295	5,226
10	20	696	100%	48%	100%	44%	45%	40%	48%	36%	53%	19,627	5,600
20	30	1074	100%	27%	100%	28%	27%	31%	27%	15%	39%	30,287	4,622
30	40	1224	100%	18%	100%	0%	10%	20%	3%	8%	30%	34,517	3,107
40	50	1114	100%	8%	100%	0%	3%	14%	0%	7%	30%	31,415	2,827
50	60	1135	100%	0%	100%	0%	0%	9%	0%	3%	30%	32,007	2,881
60	70	1157	0%	0%	0%	0%	0%	0%	0%	0%	30%	32,627	2,936
												208,483	**35,588**
												Savings	**172,895**

Install VFD on Hot Water Pump

❖ Part 2 – Find Current and Proposed Energy Use

2

OAT Bin		Bin Hours	%Flow (min 30%)	Energy Use Current (kWh)	Energy Use Proposed (kWh)
-20	-10	248	76%	6,994	4,061
-10	0	309	70%	8,714	4,328
0	10	436	65%	12,295	5,226
10	20	696	53%	19,627	5,600
20	30	1074	39%	30,287	4,622
30	40	1224	30%	34,517	3,107
40	50	1114	30%	31,415	2,827
50	60	1135	30%	32,007	2,881
60	70	1157	30%	32,627	2,936
				208,483	**35,588**
				Savings	**172,895**

Install VFD on Hot Water Pump

- Bin Hours from TMY Data

2

OAT Bin		Bin Hours	%Flow (min 30%)	Energy Use Current (kWh)	Energy Use Proposed (kWh)
-20	-10	248	76%	6,994	4,061
-10	0	309	70%	8,714	4,328
0	10	436	65%	12,295	5,226
10	20	696	53%	19,627	5,600
20	30	1074	39%	30,287	4,622
30	40	1224	30%	34,517	3,107
40	50	1114	30%	31,415	2,827
50	60	1135	30%	32,007	2,881
60	70	1157	30%	32,627	2,936
				208,483	**35,588**
				Savings	**172,895**

Install VFD on Hot Water Pump

❖ %Flow from Part 1

2

OAT Bin		Bin Hours	%Flow (min 30%)	Energy Use Current (kWh)	Energy Use Proposed (kWh)
-20	-10	248	76%	6,994	4,061
-10	0	309	70%	8,714	4,328
0	10	436	65%	12,295	5,226
10	20	696	53%	19,627	5,600
20	30	1074	39%	30,287	4,622
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50	60	1135	30%	32,007	2,881
60	70	1157	30%	32,627	2,936
				208,483	**35,588**
				Savings	**172,895**

Install VFD on Hot Water Pump

- Calculate Current and Proposed Energy Use

$$kWh = Full\ Power * \%Flow^2 * Bin\ Hours$$

2

OAT Bin		Bin Hours	%Flow (min 30%)	Energy Use Current (kWh)	Energy Use Proposed (kWh)
-20	-10	248	76%	6,994	4,061
-10	0	309	70%	8,714	4,328
0	10	436	65%	12,295	5,226
10	20	696	53%	19,627	5,600
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50	60	1135	30%	32,007	2,881
60	70	1157	30%	32,627	2,936
				208,483	**35,588**
				Savings	**172,895**

Install VFD on Hot Water Pump

❖ Calculate Energy Saving

- Saves 172,895 kWh annually, or $12,100 at 7¢/kWh or 83% of the current pump energy use.

2

OAT Bin		Bin Hours	%Flow (min 30%)	Energy Use Current (kWh)	Energy Use Proposed (kWh)
-20	-10	248	76%	6,994	4,061
-10	0	309	70%	8,714	4,328
0	10	436	65%	12,295	5,226
10	20	696	53%	19,627	5,600
20	30	1074	39%	30,287	4,622
30	40	1224	30%	34,517	3,107
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50	60	1135	30%	32,007	2,881
60	70	1157	30%	32,627	2,936
				208,483	**35,588**
				Savings	**172,895**

Install VFD on Hot Water Pump

Summary of Measure

- Keep in mind that….
  - In conjunction with adding a VFD, look at the scheduling.
  - If the AHUs have different modes of operation, account for them (Morning Warm-up etc)
- Design Considerations
  - Freeze Protection might be necessary depending on glycol level
  - Evaluate constant vs. variable flow energy use

Agenda

- Introduction
  - Trending and Trend Data
  - TMY and Bin Data
- AHU Measure
  - Optimize Airside Economizer
- Pump Measure
  - Install VFD on Hot Water Pump
- Wrap-up
- Questions

Resources

- California Commissioning Collaborative
  - www.cacx.org
- Better Bricks
  - www.betterbricks.com
- Taylor Engineering
  - www.taylor-engineering.com
- Portland Energy Conservation, Inc - PECI
  - www.peci.org

Conclusion

- Trending
  - Invaluable tool
    - Identify operational issues
    - Calculate accurate energy savings
- Spreadsheet Calculations
  - Not complicated
  - Flexible
  - Accurate
  - Worth the investment in development
- Sustainable Buildings Committee Presentation on the use of Building Automation Systems for RCx January 17th, from noon to1:00 at CEE
  (optional business meeting from 11:30 to noon)