Building Controls Strategies Conference

Retro-Commissioning with BAS Overview

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Agenda

- BAS Overview
- RCx BAS Evaluation
- Trend Data Setup & Review
- Development of Measures
- Low Cost Modifications
- Verification & Persistence of Measures
- Q & A

BAS Overview
History of Building Automation Systems

1960s – First Automated Remote Monitoring Systems for Buildings

- Limited features and functionality – primarily temperature, humidity, pressure, and status monitoring
- All monitored points connected to central panel/console
- All control functions typically performed by pneumatic/electronic controls

1970s – Multiplexing Enabled Communication Between Remote Panels

- Enabled “data gathering panels” to be located nearer to equipment being monitored
- Central computer was only “brains”; manufacturers typically built their own computers
- Proprietary programming language
- Control functions still performed by pneumatic/electric controls

1980s – Remote Panels Transition to Mini-computers

- Remote panels become “smart”; begin performing some functions of the previous generation central computer while still communicating with the central computer
- Programming still proprietary; central computers manufactured by third-party
- Conventional pneumatic control functions transition to DDC control as processing speed and hardware reliability improve

1990s – DDC Controllers Transition to Microprocessors

- Remote panels become “smarter”; control logic becomes distributed
- Central computer becomes Operator Workstation; Network Controllers contain supervisory logic
- Programming still generally proprietary

2000s – Web-Based, Open Protocol BAS Developments

- Network Controllers become web engines; Operator Workstations become Operator Interfaces
- LONWorks and BACnet dominant industry-standard open protocols, enabling data communication with various system and equipment

2010 – Present - Modern BAS Systems

- Programming becoming more “open”
- Advanced algorithms and control applications
- Becoming system integration and data visualization platform

BAS Overview
Basics

Building Automation System (BAS):

- A microprocessor-based control system that controls and monitors building systems and equipment
- Traditionally applied to mechanical/HVAC only

Building Automation System (BAS):

- Technology enabling connectivity to many more types of equipment and systems:
  - Lighting Control Systems
  - Plumbing/Fire Protection
  - Electrical Power and Distribution
  - Fire Alarm
  - Security – Video Surveillance and Access Control
  - Vertical Transportation (Elevators, Escalators)
  - Metering

RCx BAS Evaluation
First Questions

1. BAS Configuration – History, Consistent System, Pneumatic Hybrid, etc.
2. BAS Settings – Sequences on Auto or Disabled? Set Points Fixed or Variable?
3. Operator Interview – Interview operator(s) to determine level of comfort with the BAS, when overrides are used, etc.
4. Trending – Is it setup and if so how is it setup?
5. Design Documents – Original Sequence of Operations, Controls Drawings, and As-Built HVAC Drawings.

RCx BAS Evaluation
BAS Configuration

1. Software Upgrade History
   - Newer versions are often web based and can be more easily remote accessed
2. Hardware Upgrade History
   - Are controllers consistent? Combining different generations of master and field controllers can lead to communication issues.
3. Pneumatic / DDC Hybrid Systems
   - Where does DDC end and pneumatic begin?
   - What limitations are created?

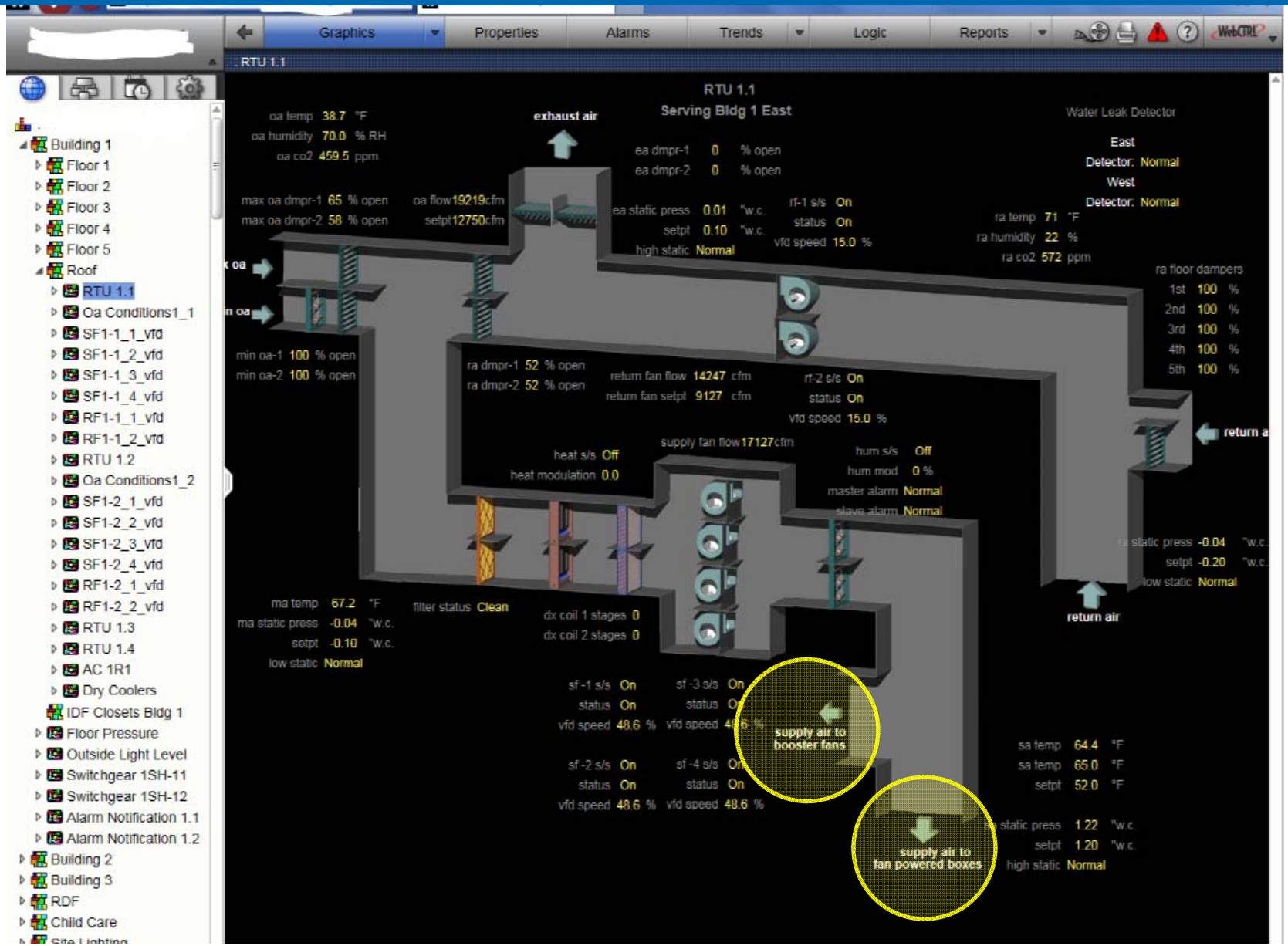
RCx BAS Evaluation
BAS Settings

1. Control Sequences
   - Which Sequences can/cannot be Overridden?
   - Auto or Manual Override?
   - Are Common Sequences Implemented?
     - Static Pressure Reset
     - DAT, CHW, CW Reset
2. Schedules
   - Is Optimum Start Used?
   - Are Schedules Overridden During Extreme Weather?

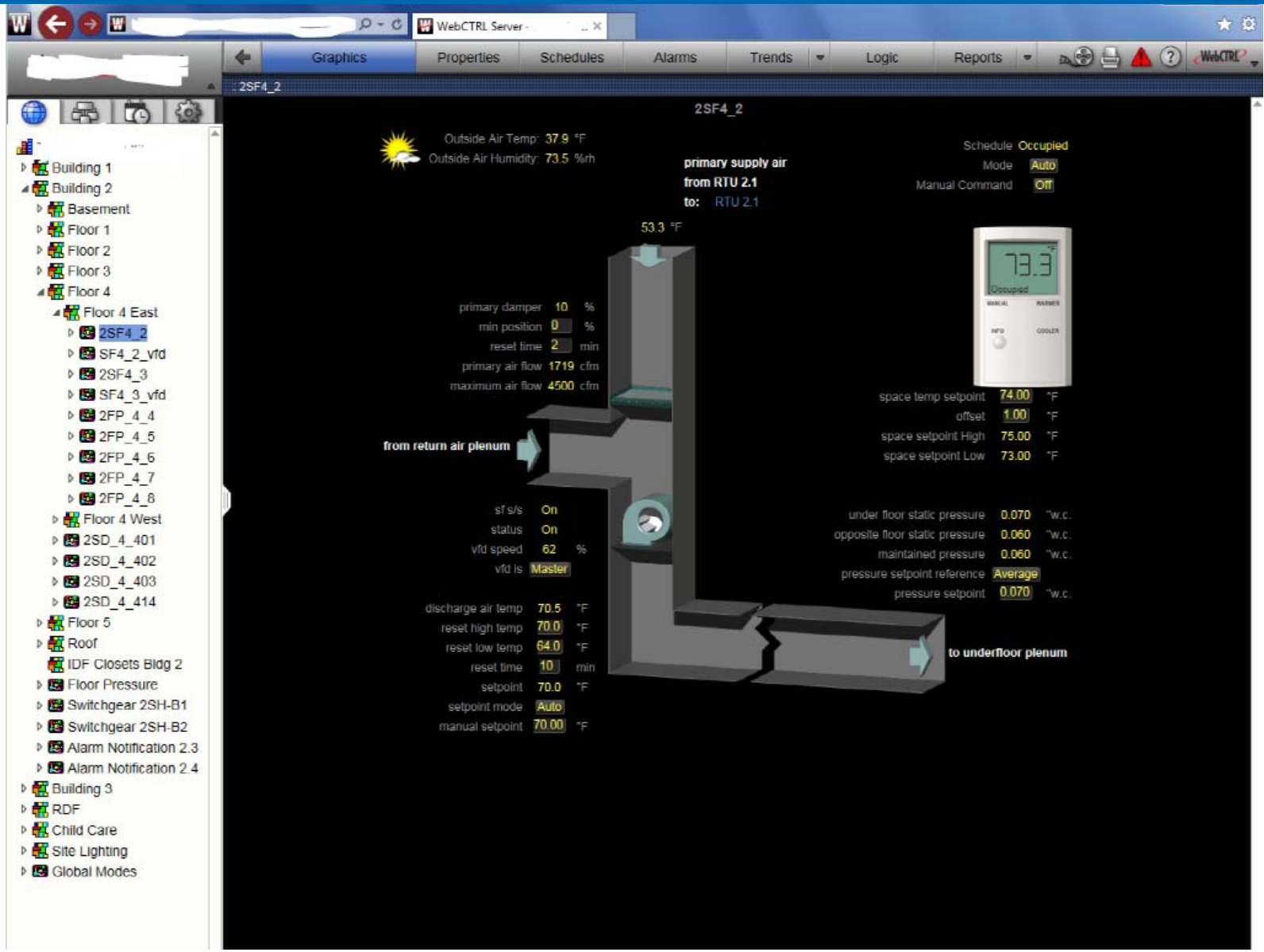
RCx BAS Evaluation
BAS Settings - Familiarization

1. Attempt to Understand System from Operator's Perspective
2. Do Sensor Values Make Sense?
   - Bad sensors often apparent at a glance
3. What Alarms are Present?
4. What Limitations do You See?
   - Pretend you are the operator – what tasks would you need to perform?

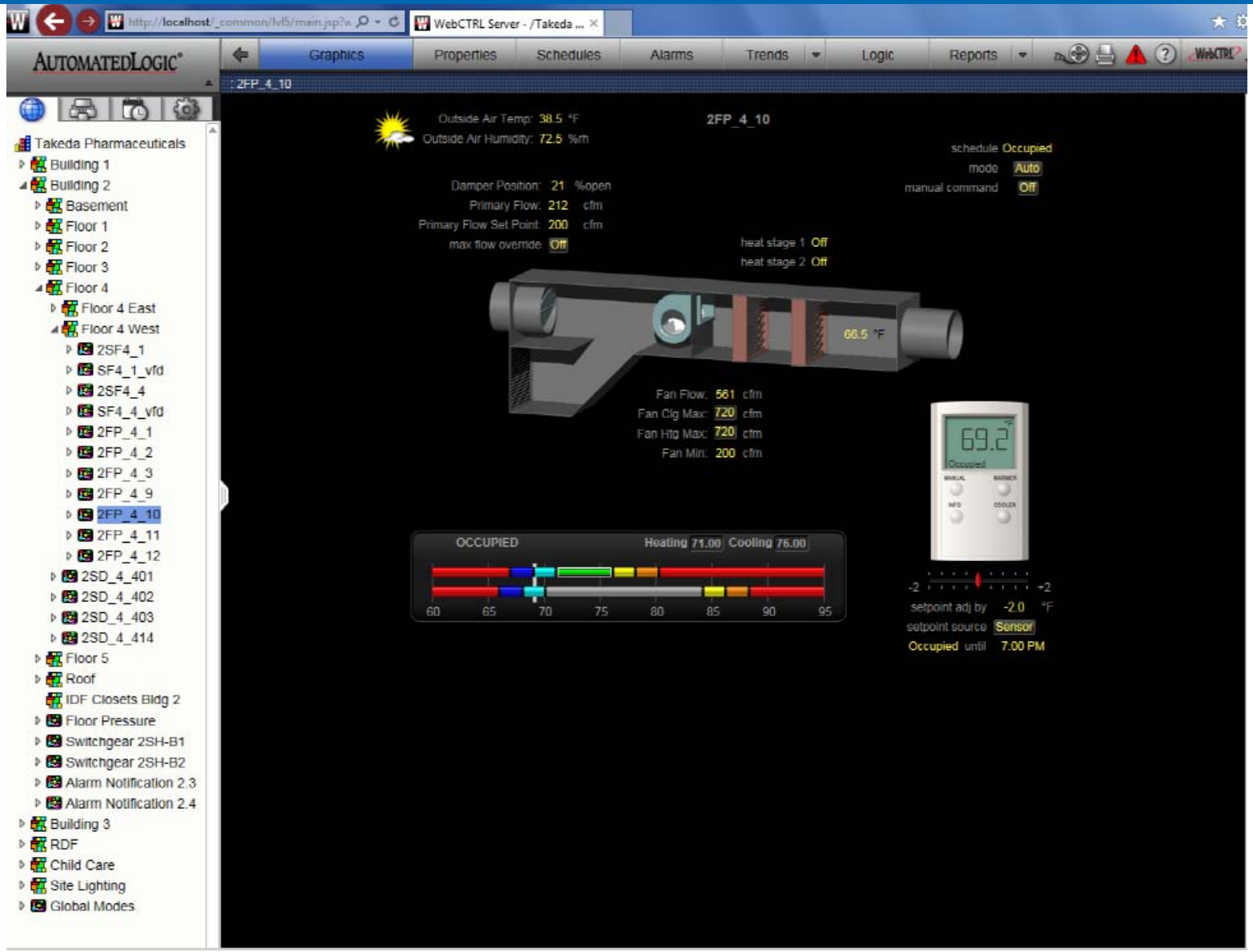
RCx BAS Evaluation
Example BAS Graphics – Rooftop Unit



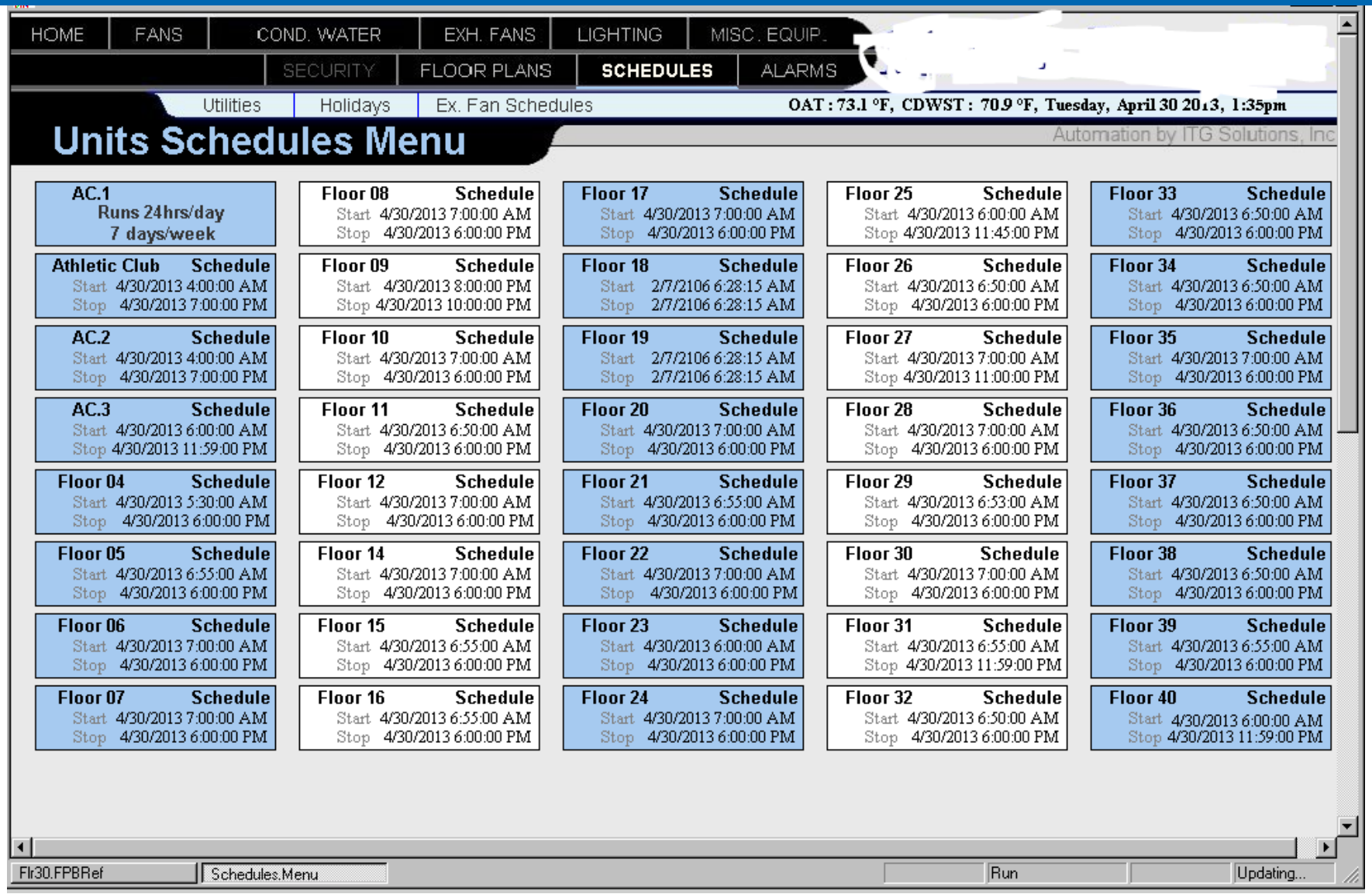
RCx BAS Evaluation
Example BAS Graphics – UFAD Booster Fan



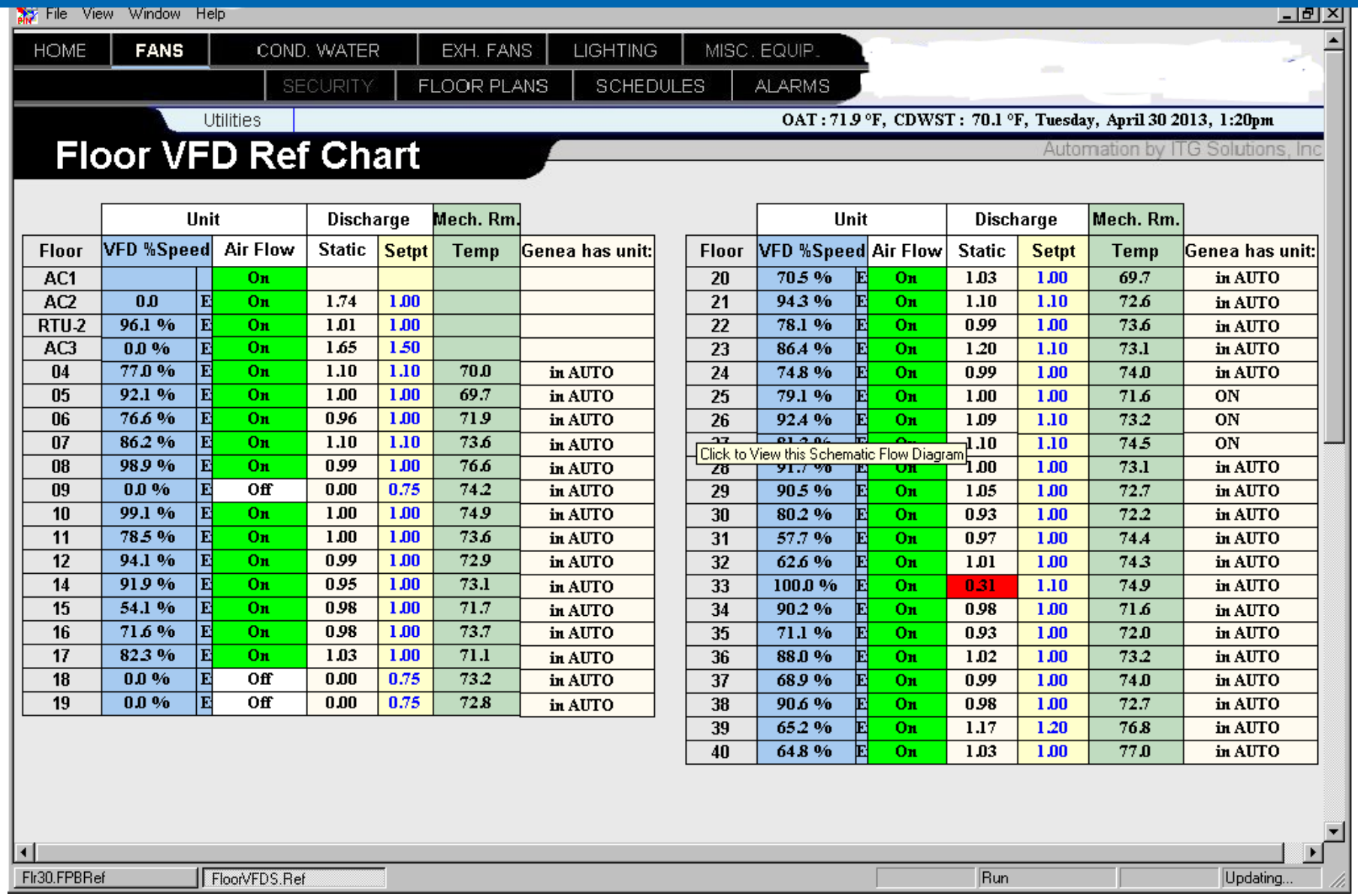
RCx BAS Evaluation
Example BAS Graphics – Fan-Powered Box



RCx BAS Evaluation
Example BAS Graphics – Tabular Graphics



RCx BAS Evaluation
Example BAS Graphics – Tabular Graphics



File View Window Help

HOME | FANS | COND. WATER | EXH. FANS | LIGHTING | MISC. EQUIP.
SECURITY | FLOOR PLANS | SCHEDULES | ALARMS

Utilities

OAT : 71.9 °F, CDWST : 70.1 °F, Tuesday, April 30 2013, 1:20pm

Floor VFD Ref Chart

Automation by ITG Solutions, Inc

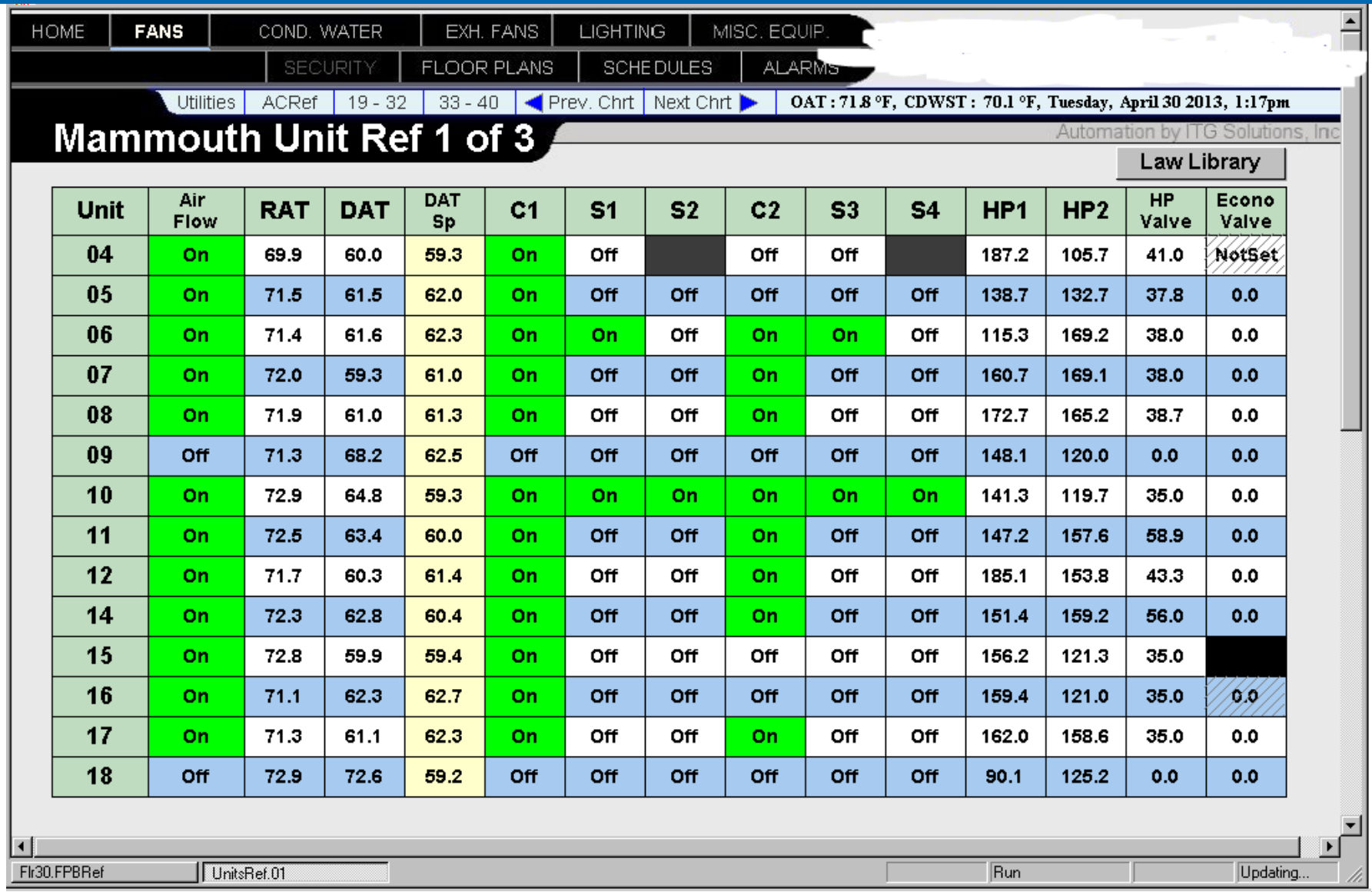
	Unit			Discharge		Mech. Rm.	
Floor	VFD %Speed		Air Flow	Static	Setpt	Temp	Genea has unit:
AC1			On				
AC2	0.0	E	On	1.74	1.00		
RTU-2	96.1 %	E	On	1.01	1.00		
AC3	0.0 %	E	On	1.65	1.50		
04	77.0 %	E	On	1.10	1.10	70.0	in AUTO
05	92.1 %	E	On	1.00	1.00	69.7	in AUTO
06	76.6 %	E	On	0.96	1.00	71.9	in AUTO
07	86.2 %	E	On	1.10	1.10	73.6	in AUTO
08	98.9 %	E	On	0.99	1.00	76.6	in AUTO
09	0.0 %	E	Off	0.00	0.75	74.2	in AUTO
10	99.1 %	E	On	1.00	1.00	74.9	in AUTO
11	78.5 %	E	On	1.00	1.00	73.6	in AUTO
12	94.1 %	E	On	0.99	1.00	72.9	in AUTO
14	91.9 %	E	On	0.95	1.00	73.1	in AUTO
15	54.1 %	E	On	0.98	1.00	71.7	in AUTO
16	71.6 %	E	On	0.98	1.00	73.7	in AUTO
17	82.3 %	E	On	1.03	1.00	71.1	in AUTO
18	0.0 %	E	Off	0.00	0.75	73.2	in AUTO
19	0.0 %	E	Off	0.00	0.75	72.8	in AUTO

	Unit			Discharge		Mech. Rm.	
Floor	VFD %Speed		Air Flow	Static	Setpt	Temp	Genea has unit:
20	70.5 %	E	On	1.03	1.00	69.7	in AUTO
21	94.3 %	E	On	1.10	1.10	72.6	in AUTO
22	78.1 %	E	On	0.99	1.00	73.6	in AUTO
23	86.4 %	E	On	1.20	1.10	73.1	in AUTO
24	74.8 %	E	On	0.99	1.00	74.0	in AUTO
25	79.1 %	E	On	1.00	1.00	71.6	ON
26	92.4 %	E	On	1.09	1.10	73.2	ON
27	81.2 %	E	On	1.10	1.10	74.5	ON
28	91.7 %	E	On	1.00	1.00	73.1	in AUTO
29	90.5 %	E	On	1.05	1.00	72.7	in AUTO
30	80.2 %	E	On	0.93	1.00	72.2	in AUTO
31	57.7 %	E	On	0.97	1.00	74.4	in AUTO
32	62.6 %	E	On	1.01	1.00	74.3	in AUTO
33	100.0 %	E	On	0.31	1.10	74.9	in AUTO
34	90.2 %	E	On	0.98	1.00	71.6	in AUTO
35	71.1 %	E	On	0.93	1.00	72.0	in AUTO
36	88.0 %	E	On	1.02	1.00	73.2	in AUTO
37	68.9 %	E	On	0.99	1.00	74.0	in AUTO
38	90.6 %	E	On	0.98	1.00	72.7	in AUTO
39	65.2 %	E	On	1.17	1.20	76.8	in AUTO
40	64.8 %	E	On	1.03	1.00	77.0	in AUTO

Click to View this Schematic Flow Diagram

Flr30.FPBRef | FloorVFDS.Ref | Run | Updating...

RCx BAS Evaluation
Example BAS Graphics – Tabular Graphics



HOME | FANS | COND. WATER | EXH. FANS | LIGHTING | MISC. EQUIP.
SECURITY | FLOOR PLANS | SCHEDULES | ALARMS
Utilities | ACRef | 19 - 32 | 33 - 40 | ◀ Prev. Chrt | Next Chrt ▶ | OAT : 71.8 °F, CDWST : 70.1 °F, Tuesday, April 30 2013, 1:17pm

Mammouth Unit Ref 1 of 3

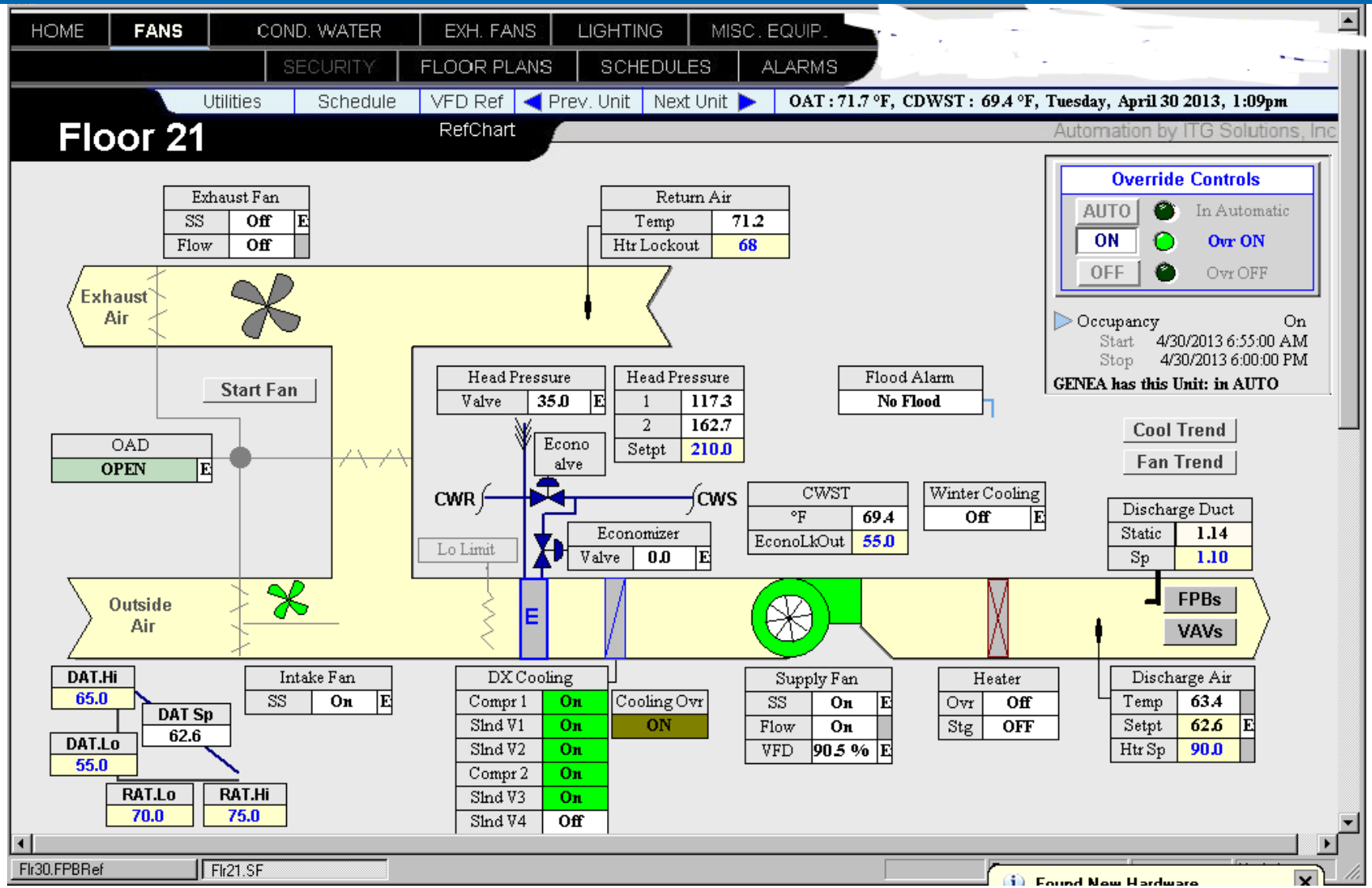
Automation by ITG Solutions, Inc

Law Library

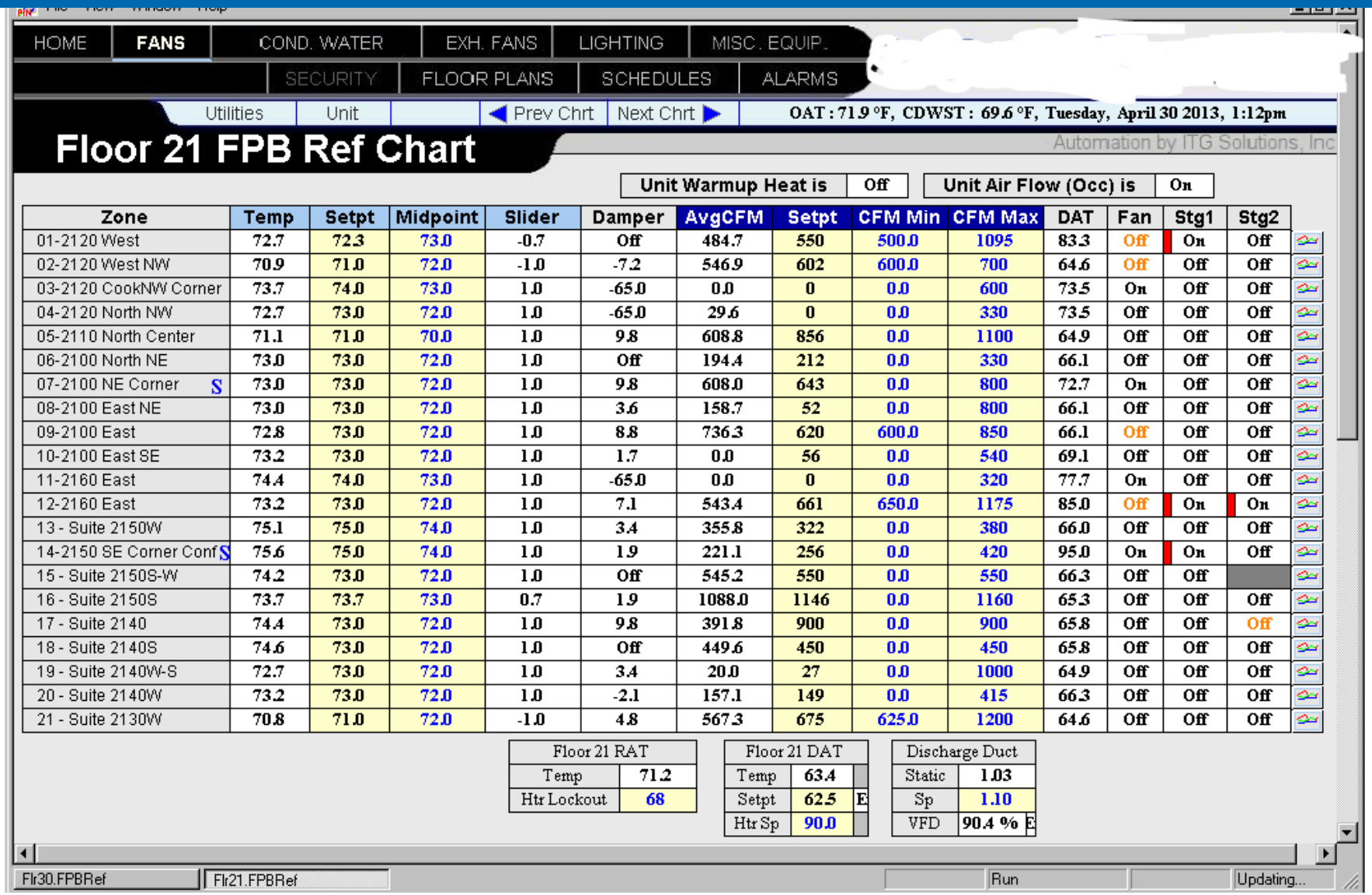
Unit	Air Flow	RAT	DAT	DAT Sp	C1	S1	S2	C2	S3	S4	HP1	HP2	HP Valve	Econo Valve
04	On	69.9	60.0	59.3	On	Off		Off	Off		187.2	105.7	41.0	NotSet
05	On	71.5	61.5	62.0	On	Off	Off	Off	Off	Off	138.7	132.7	37.8	0.0
06	On	71.4	61.6	62.3	On	On	Off	On	On	Off	115.3	169.2	38.0	0.0
07	On	72.0	59.3	61.0	On	Off	Off	On	Off	Off	160.7	169.1	38.0	0.0
08	On	71.9	61.0	61.3	On	Off	Off	On	Off	Off	172.7	165.2	38.7	0.0
09	Off	71.3	68.2	62.5	Off	Off	Off	Off	Off	Off	148.1	120.0	0.0	0.0
10	On	72.9	64.8	59.3	On	On	On	On	On	On	141.3	119.7	35.0	0.0
11	On	72.5	63.4	60.0	On	Off	Off	On	Off	Off	147.2	157.6	58.9	0.0
12	On	71.7	60.3	61.4	On	Off	Off	On	Off	Off	185.1	153.8	43.3	0.0
14	On	72.3	62.8	60.4	On	Off	Off	On	Off	Off	151.4	159.2	56.0	0.0
15	On	72.8	59.9	59.4	On	Off	Off	Off	Off	Off	156.2	121.3	35.0	
16	On	71.1	62.3	62.7	On	Off	Off	Off	Off	Off	159.4	121.0	35.0	0.0
17	On	71.3	61.1	62.3	On	Off	Off	On	Off	Off	162.0	158.6	35.0	0.0
18	Off	72.9	72.6	59.2	Off	Off	Off	Off	Off	Off	90.1	125.2	0.0	0.0

Flr30.FPBRef | UnitsRef.01 | Run | Updating...

RCx BAS Evaluation
Example BAS Graphics – Tabular Graphics



RCx BAS Evaluation
Example BAS Graphics – Tabular Graphics



HOME | FANS | COND. WATER | EXH. FANS | LIGHTING | MISC. EQUIP.
SECURITY | FLOOR PLANS | SCHEDULES | ALARMS

Utilities | Unit | ◀ Prev Chrt | Next Chrt ▶ | OAT : 71.9 °F, CDWST : 69.6 °F, Tuesday, April 30 2013, 1:12pm

Floor 21 FPB Ref Chart

Automation by ITG Solutions, Inc

Unit Warmup Heat is	Off	Unit Air Flow (Occ) is	On

Zone	Temp	Setpt	Midpoint	Slider	Damper	AvgCFM	Setpt	CFM Min	CFM Max	DAT	Fan	Stg1	Stg2
01-2120 West	72.7	72.3	73.0	-0.7	Off	484.7	550	500.0	1095	83.3	Off	On	Off
02-2120 West NW	70.9	71.0	72.0	-1.0	-7.2	546.9	602	600.0	700	64.6	Off	Off	Off
03-2120 CookNW Corner	73.7	74.0	73.0	1.0	-65.0	0.0	0	0.0	600	73.5	On	Off	Off
04-2120 North NW	72.7	73.0	72.0	1.0	-65.0	29.6	0	0.0	330	73.5	Off	Off	Off
05-2110 North Center	71.1	71.0	70.0	1.0	9.8	608.8	856	0.0	1100	64.9	Off	Off	Off
06-2100 North NE	73.0	73.0	72.0	1.0	Off	194.4	212	0.0	330	66.1	Off	Off	Off
07-2100 NE Corner S	73.0	73.0	72.0	1.0	9.8	608.0	643	0.0	800	72.7	On	Off	Off
08-2100 East NE	73.0	73.0	72.0	1.0	3.6	158.7	52	0.0	800	66.1	Off	Off	Off
09-2100 East	72.8	73.0	72.0	1.0	8.8	736.3	620	600.0	850	66.1	Off	Off	Off
10-2100 East SE	73.2	73.0	72.0	1.0	1.7	0.0	56	0.0	540	69.1	Off	Off	Off
11-2160 East	74.4	74.0	73.0	1.0	-65.0	0.0	0	0.0	320	77.7	On	Off	Off
12-2160 East	73.2	73.0	72.0	1.0	7.1	543.4	661	650.0	1175	85.0	Off	On	On
13 - Suite 2150W	75.1	75.0	74.0	1.0	3.4	355.8	322	0.0	380	66.0	Off	Off	Off
14-2150 SE Corner Conf S	75.6	75.0	74.0	1.0	1.9	221.1	256	0.0	420	95.0	On	On	Off
15 - Suite 2150S-W	74.2	73.0	72.0	1.0	Off	545.2	550	0.0	550	66.3	Off	Off	
16 - Suite 2150S	73.7	73.7	73.0	0.7	1.9	1088.0	1146	0.0	1160	65.3	Off	Off	Off
17 - Suite 2140	74.4	73.0	72.0	1.0	9.8	391.8	900	0.0	900	65.8	Off	Off	Off
18 - Suite 2140S	74.6	73.0	72.0	1.0	Off	449.6	450	0.0	450	65.8	Off	Off	Off
19 - Suite 2140W-S	72.7	73.0	72.0	1.0	3.4	20.0	27	0.0	1000	64.9	Off	Off	Off
20 - Suite 2140W	73.2	73.0	72.0	1.0	-2.1	157.1	149	0.0	415	66.3	Off	Off	Off
21 - Suite 2130W	70.8	71.0	72.0	-1.0	4.8	567.3	675	625.0	1200	64.6	Off	Off	Off

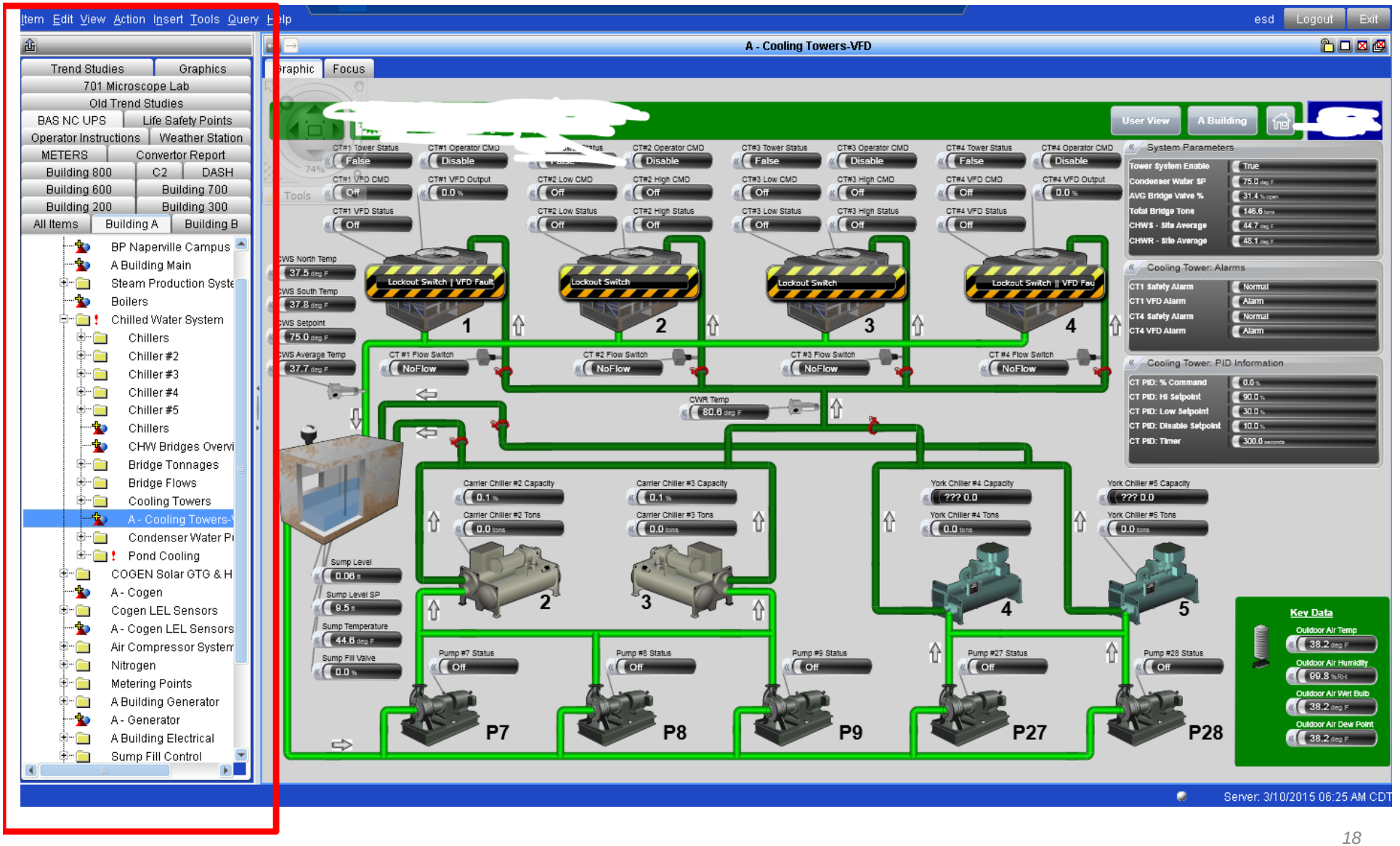
Floor 21 RAT	
Temp	71.2
Htr Lockout	68

Floor 21 DAT		
Temp	63.4	
Setpt	62.5	E
Htr Sp	90.0	

Discharge Duct		
Static	1.03	
Sp	1.10	
VFD	90.4 %	E

Flr30.FPBRef | Flr21.FPBRef | Run | Updating...

RCx BAS Evaluation
Example BAS Graphics – Campus



RCx BAS Evaluation
Operator Interview

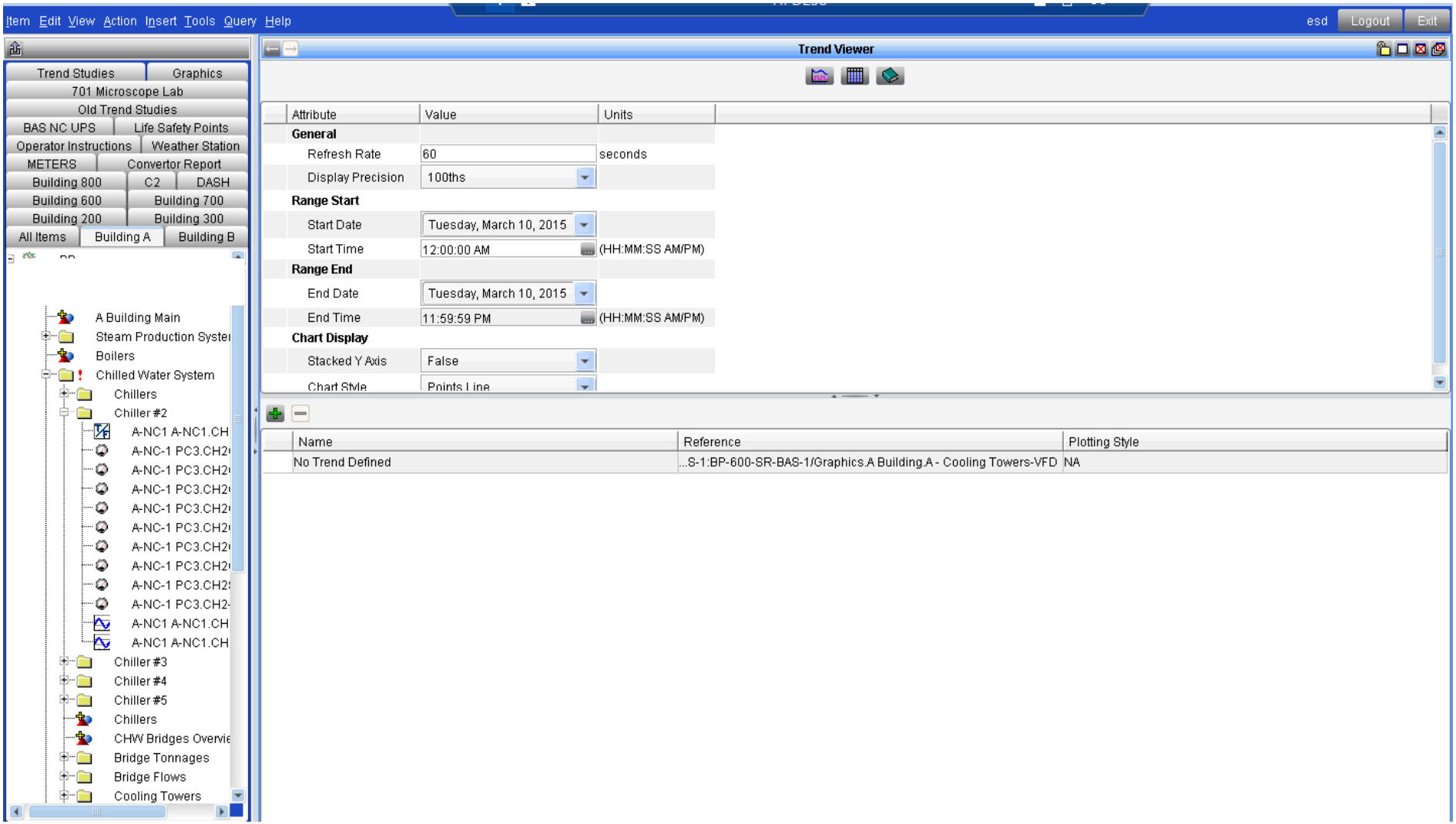
1. Operator Comfort Level
   - High comfort level usually leads to better operator buy-in
   - If comfort level low, it is important to restore their confidence
2. Why are Certain Sequences Overridden?
   - Usually the sequence works, but associated sensors, controllers, or other prevent proper operation
   - “We’ve always done it this way” is also a common answer
   - If you cannot prevent operators from overriding your retro-commissioning measures, the project cannot succeed
3. What else is Performed Manually?
   - Commonly there are season specific operating SOPs (24/7 operation during extreme conditions, etc.)
   - Set points are often changed manually as needed (or perceived to be needed)
4. What Would You Change?

RCx BAS Evaluation
Trending

1. What are trending capabilities of BAS?
2. If trending is setup, how is it setup?
   - Intervals or change of state?
   - Interval length?
     - 15 minutes is most common, followed by 30 minutes
   - Trending duration?
     - Often 2 weeks or less
     - As an RCx agent, more data is always better
3. Can trending be easily setup, or will controls contractor be required?
4. Are there cases where data loggers will be required?

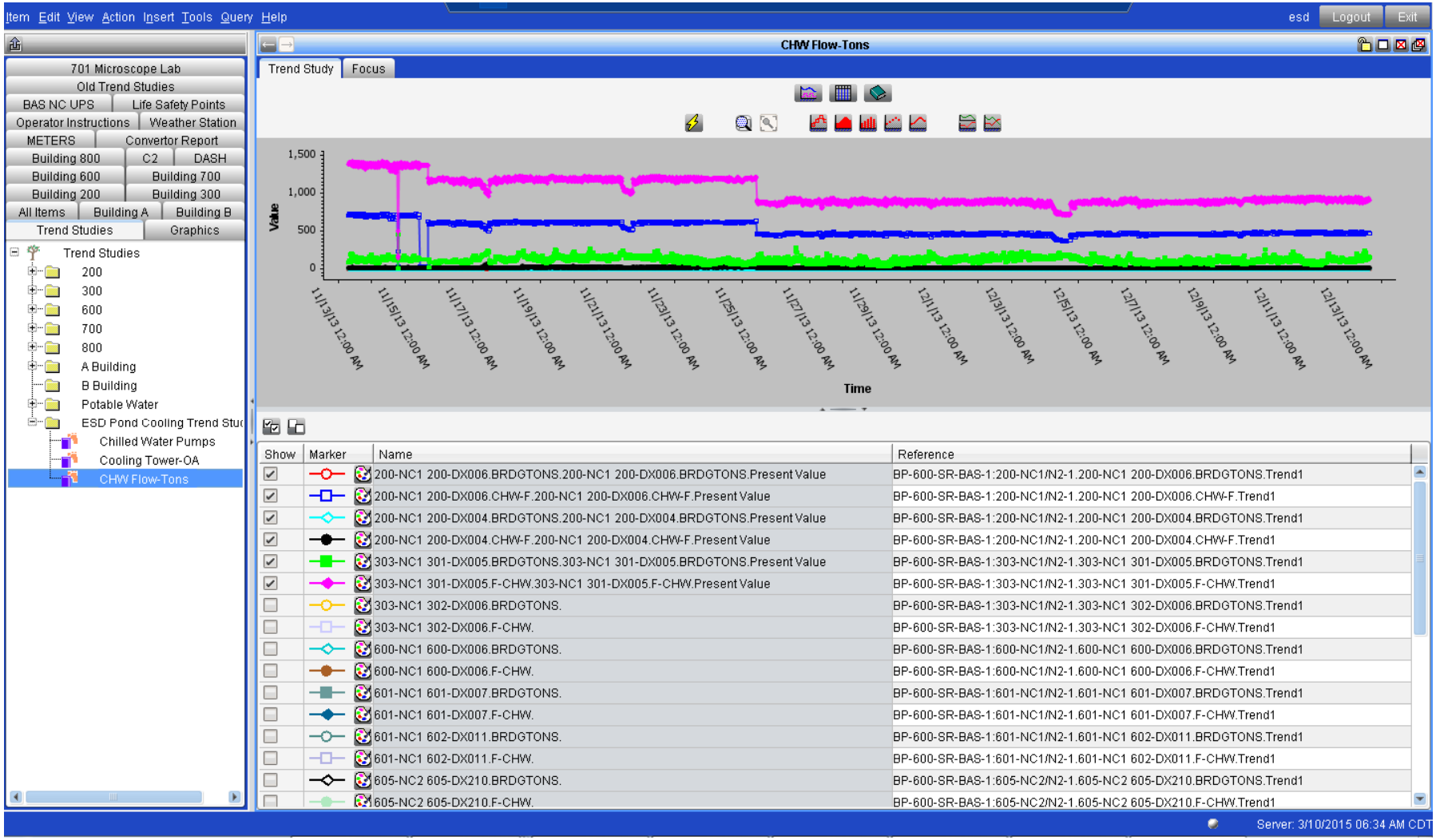
RCx BAS Evaluation

Trending – Example Trend Retrieval – Open Trend Viewer



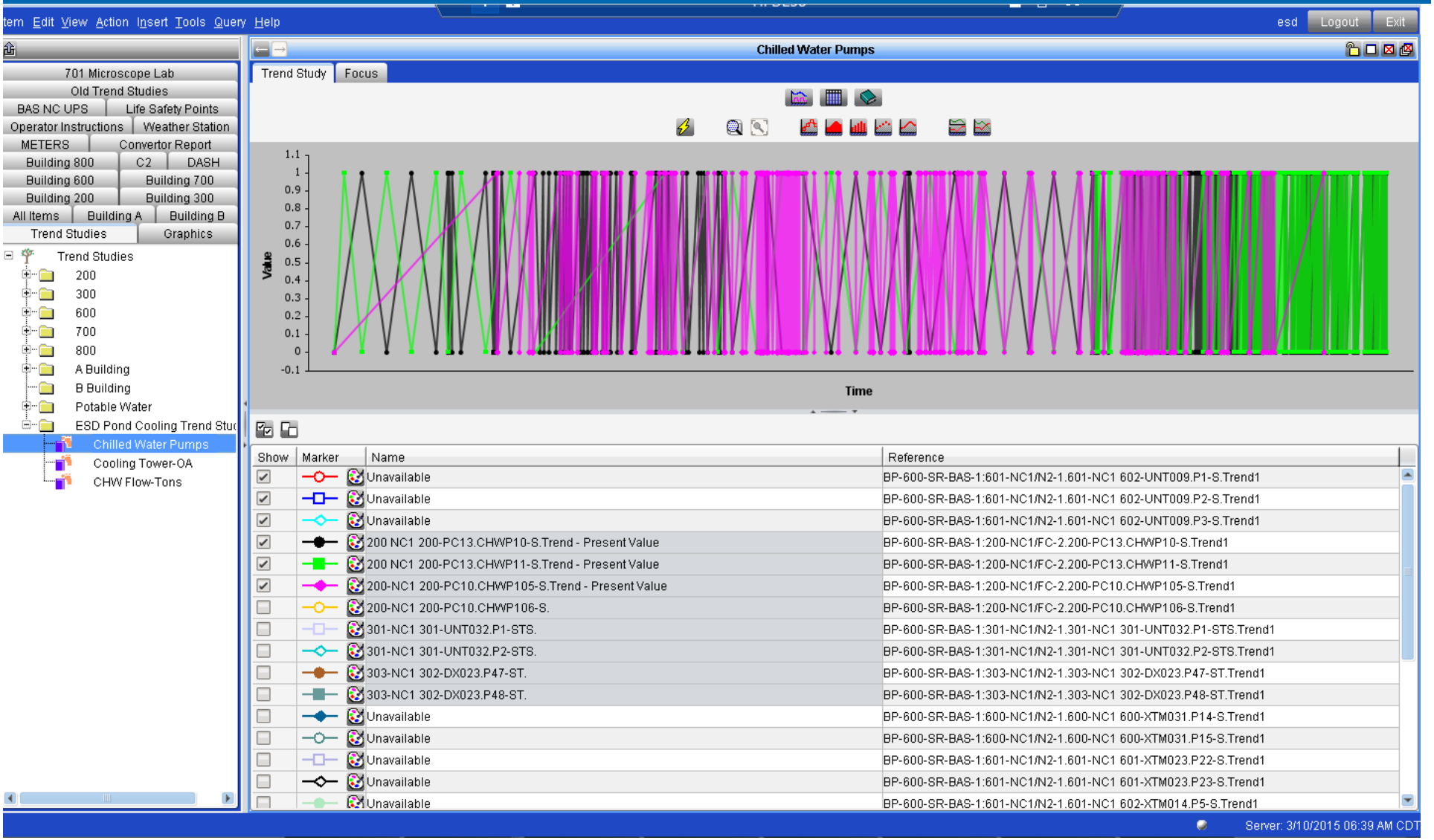
RCx BAS Evaluation

Trending – Example Trend Retrieval – Select Point(s) and Parameters



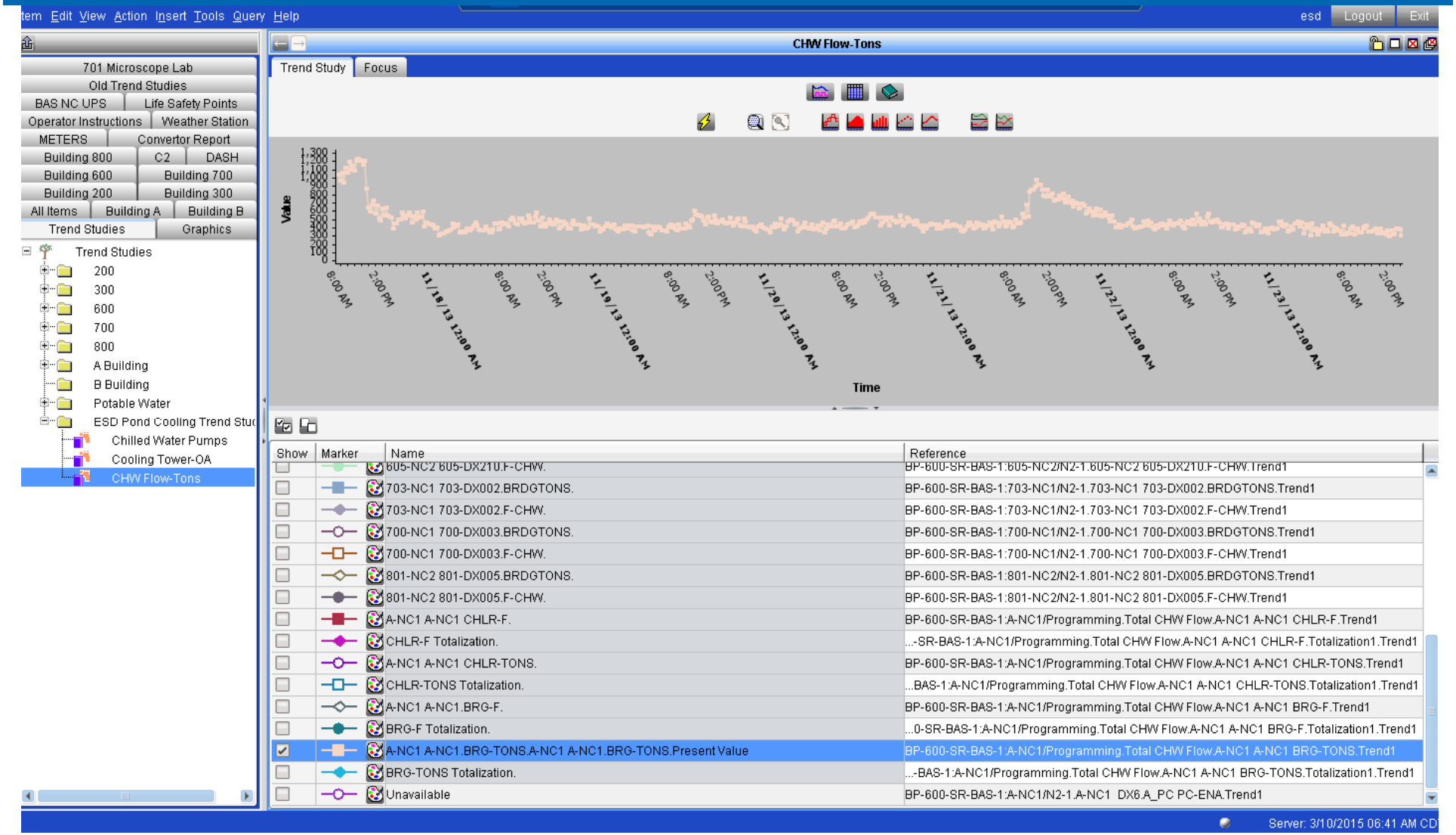
RCx BAS Evaluation

Trending – Example Trend Retrieval – Select Useful View



RCx BAS Evaluation

Trending – Example Trend Retrieval – Select Useful View



RCx BAS Evaluation
Design Documents

1. What is available? Is documentation accurate?
2. Determine design intent and compare this to current configuration / operational strategy – what are the reasons for differences?
3. Is installed BAS the original BAS? If not has functionality been lost since original design was constructed?
4. Determine if differences are favorable or negative – if negative is there a low cost resolution?

Trend Data Setup and Review
Assessing Setup and Needs

1. How will you use the data?
   - Graphical review is very effective for identifying operational issues and trends
   - If savings of ECMs must be quantified, trend data in numerical format from before and after will be required
2. Do timestamps align?
   - Perfect alignment of all timestamps for all points in a given BAS is very rare, even if configured to be aligned (controller losses of communication)
   - If data must be used for calculations, the timestamps need to be aligned by the BAS, or data must be post-processed to align data with varying timestamp intervals or gaps in data

Trend Data Setup and Review
Choosing a Setup

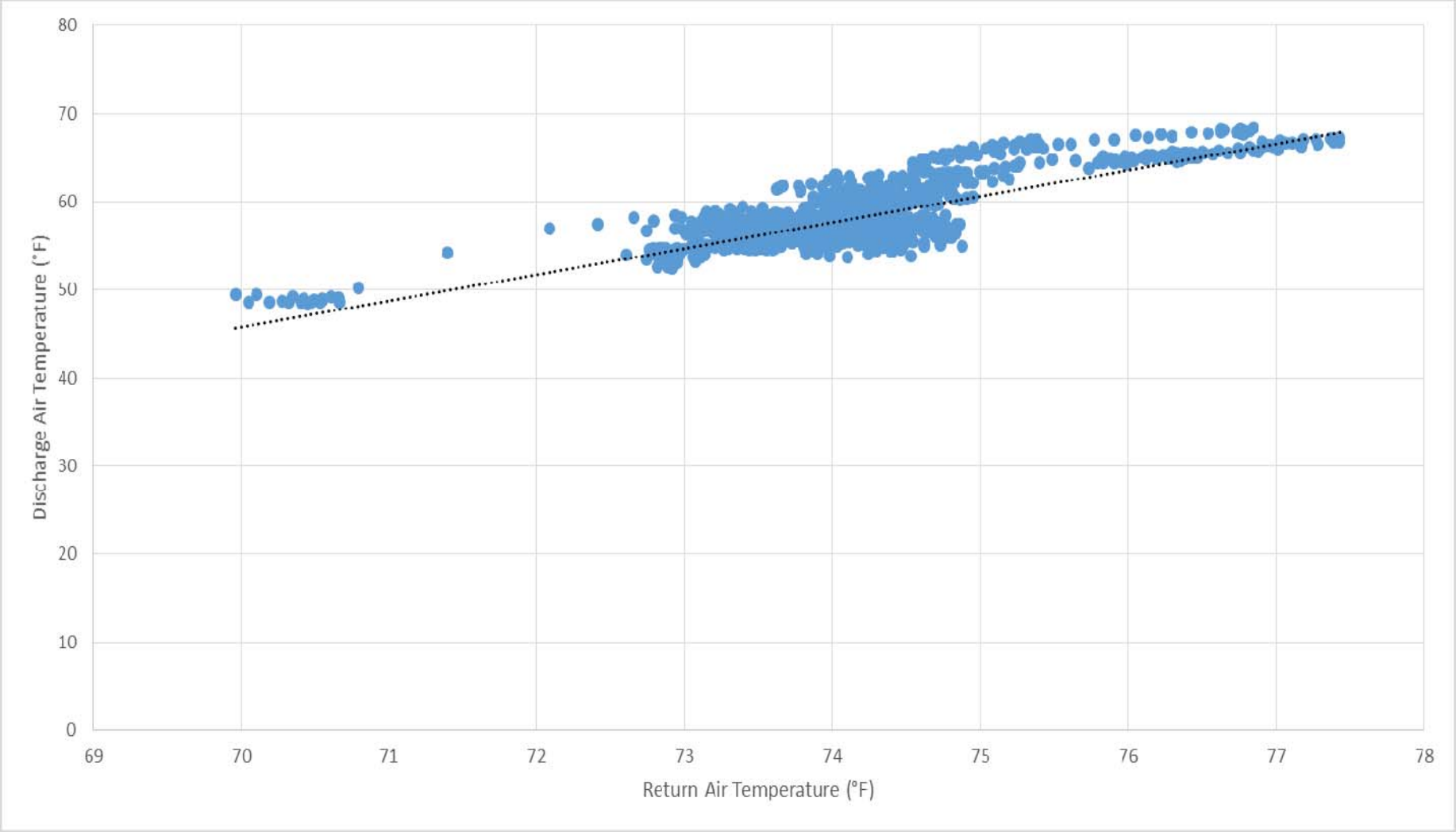
1. Must be useful, without exceeding BAS capabilities
   - Excessive trending can slow down systems
   - Ideally data is pulled from controllers in early morning
2. Shorter duration provides better resolution of data, but greater memory requirements
   - Typically 15 minutes is adequate especially for buildings that are hot water and chilled water, with PID loop control
   - For equipment that cycles often, such as DX compressors, a shorter time interval or change of value trending interval may be preferred
3. How can trend review process be streamlined?
   - If data must be pulled numerous times, process must be considered
   - Things as simple as point naming conventions can make a huge difference in effort required
4. Are there any instances where data loggers should be substituted for missing or unreliable points?

Trend Data Setup and Review
Reviewing Trend Data

1. Review for ECM development
   - Utility programs generally require Microsoft Excel calculations
2. Review to identify operational issues
   - Graphical review is often most useful
   - Fastest understanding achieved by graphing associated points
3. Sorting and timestamp alignment
   - Timestamps must align, or specialty software must be used
   - Universal Translator 2/3
4. Use of weather station data
   - Is site weather data reliable?
   - Generally worthwhile to use a weather station as a reference regardless of site OA measurement capabilities
   - Often systems lack outside air humidity sensor (humidity sensors in general)

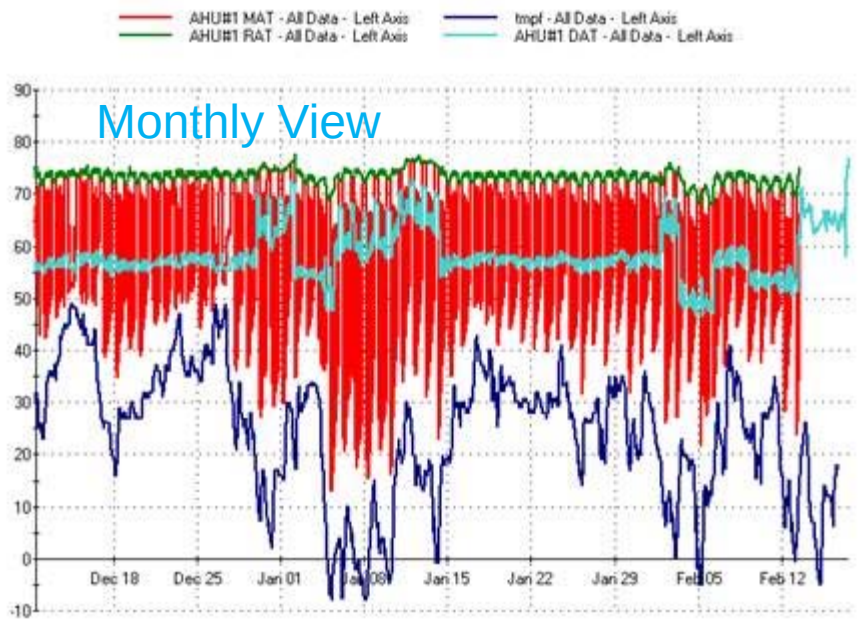
Trend Data Setup and Review

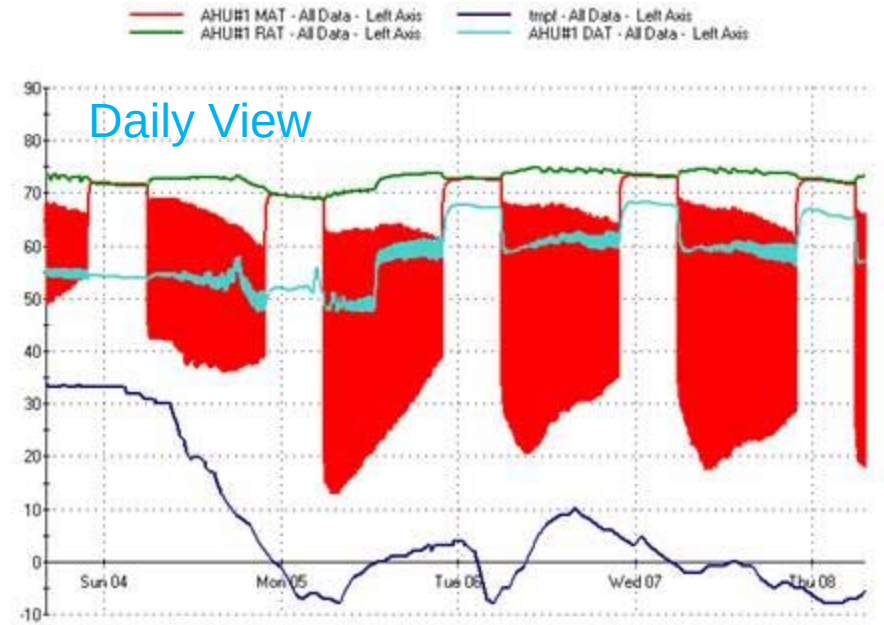
Reviewing Trend Data Examples – DAT Reset (Point vs. Point)

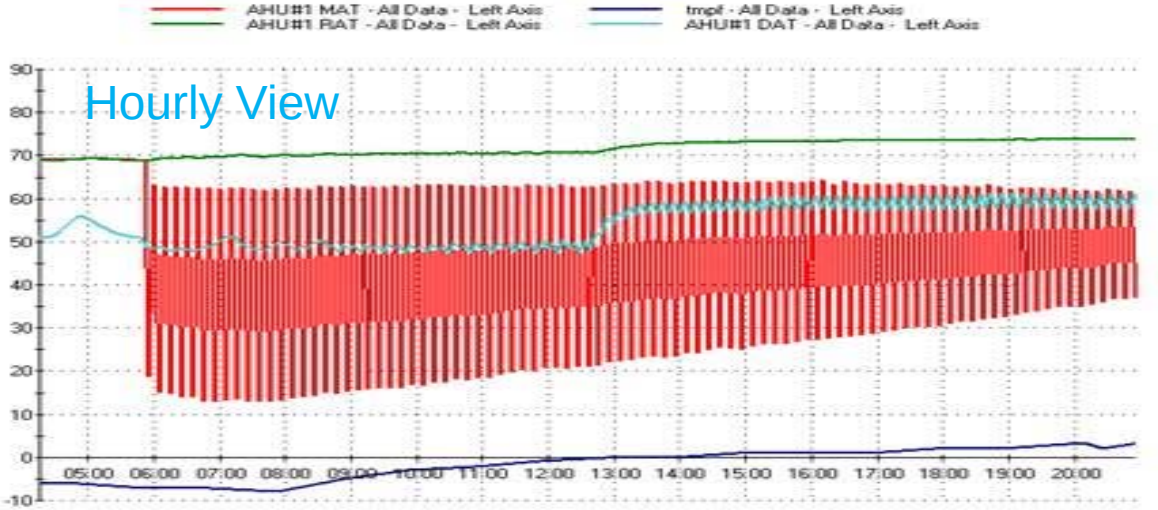


Trend Data Setup and Review

Reviewing Trend Data Examples – Enthalpy Economizer (Time Lapse)







Development of Measures
Starting Points

1. Review trend data, sequence of operations, design drawings, and interview findings
2. Develop preliminary ECM list based on energy saving opportunities
3. What associated control points are available?
4. Of available control points which are most reliable?
5. How may system limitations be worked around to develop sequences for ECMs?
6. Consider possible interactions between sequences to ensure sequences compliment each other
7. Are there difficult limitations to overcome? Often low cost measures fall outside of utility sponsored RCx scope

Development of Measures
Selection of Measures

1. In utility funded RCx programs, 1.5 year payback can be a limiting factor
2. Though there may be an energy savings basis for a measure, is there a low cost solution to achievement?
   - Are proper control points present?
   - Are there costs associated with implementation, beyond revised control sequences?
   - Sensor addition, replacement, or calibration is usually considered low cost, but additional steps to implementation may be beyond RC scope
3. Generally becomes a list of control sequences for RCx implementation, and capital measures that are outside of RCx scope for later consideration

Development of Measures
Most Common Measures

1. Scheduling / Optimum Start
2. Static Pressure Reset
3. Discharge Air Temperature Reset
4. Condenser Water Reset
5. Chilled Water Reset
6. Terminal Unit Primary Minimums
7. Economizer Control
8. Deadband Modifications
9. Night Setback
10. Damper Scheduling
11. Demand Controlled Ventilation

Development of Measures
Programming Languages

1. Logic Diagrams
   - Canned calculation blocks Increasingly more common
   - More user-friendly to programmer
   - Can create limitations in very custom situations
2. Text Based
   - Similar to C, FORTRAN, other text based programming languages (else, and, or, if statements, etc.)
   - Completely custom programming, though “canned” logic covers most cases
   - Generally preferred by experienced programmers

Advanced considerations for an RCx agent, but worth knowing

Development of Measures
Example Measures – Operator Adjustable DAT Set Point vs. Reset

1. Constant Volume System, with Steam Reheat and Perimeter Induction Units.
   - Winter interior cooling load satisfied with 62°F supply air
   - Summer set point was manually adjusted as low as 50°F
2. Manual Set Point Reduction Occurred when Humidity Issues were Observed
   - During summer latent cooling loads are highest, because of OA humidity + people latent load
   - During winter latent cooling load is people only, which is mostly satisfied with dry outside air (ventilation)
3. Sequence Implemented to Reset Discharge Air Temperature Set Point, Based on Return Air Humidity
   - Substantial savings resulting from excess dehumidification caused by operator overrides to 50°F DAT set point
   - After implementation, set point was higher on average, but no thermal comfort issues were reported

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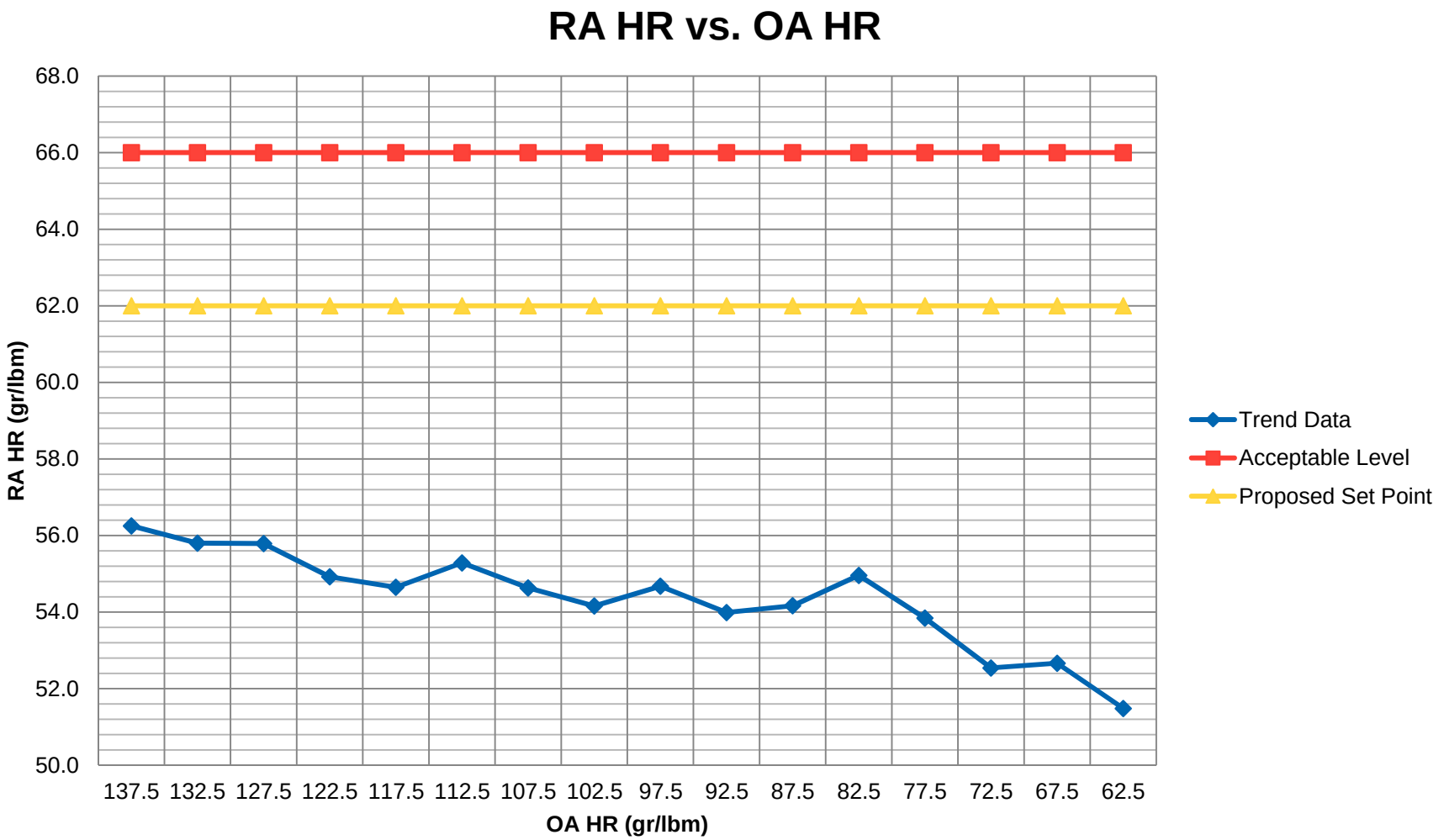

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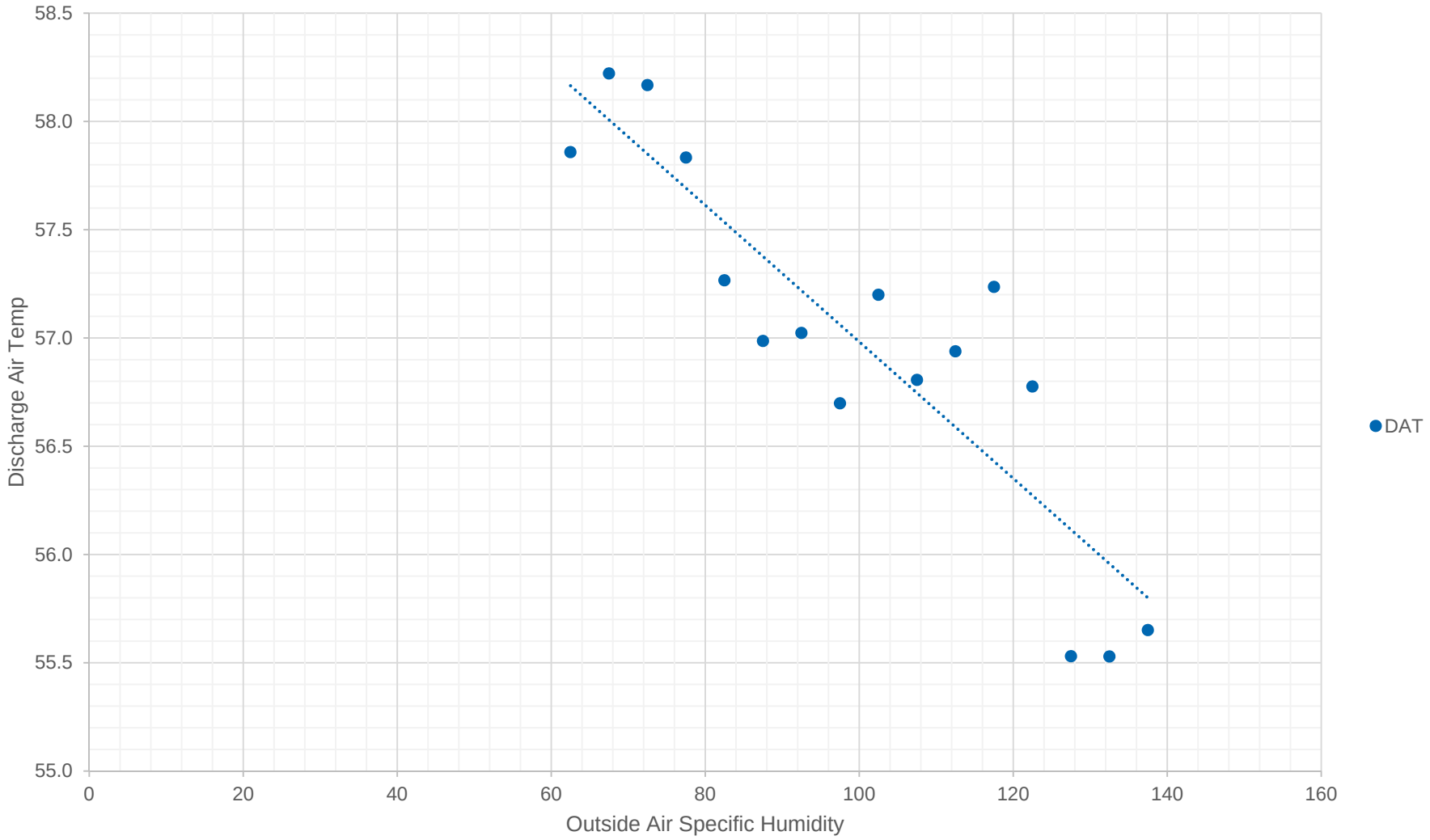

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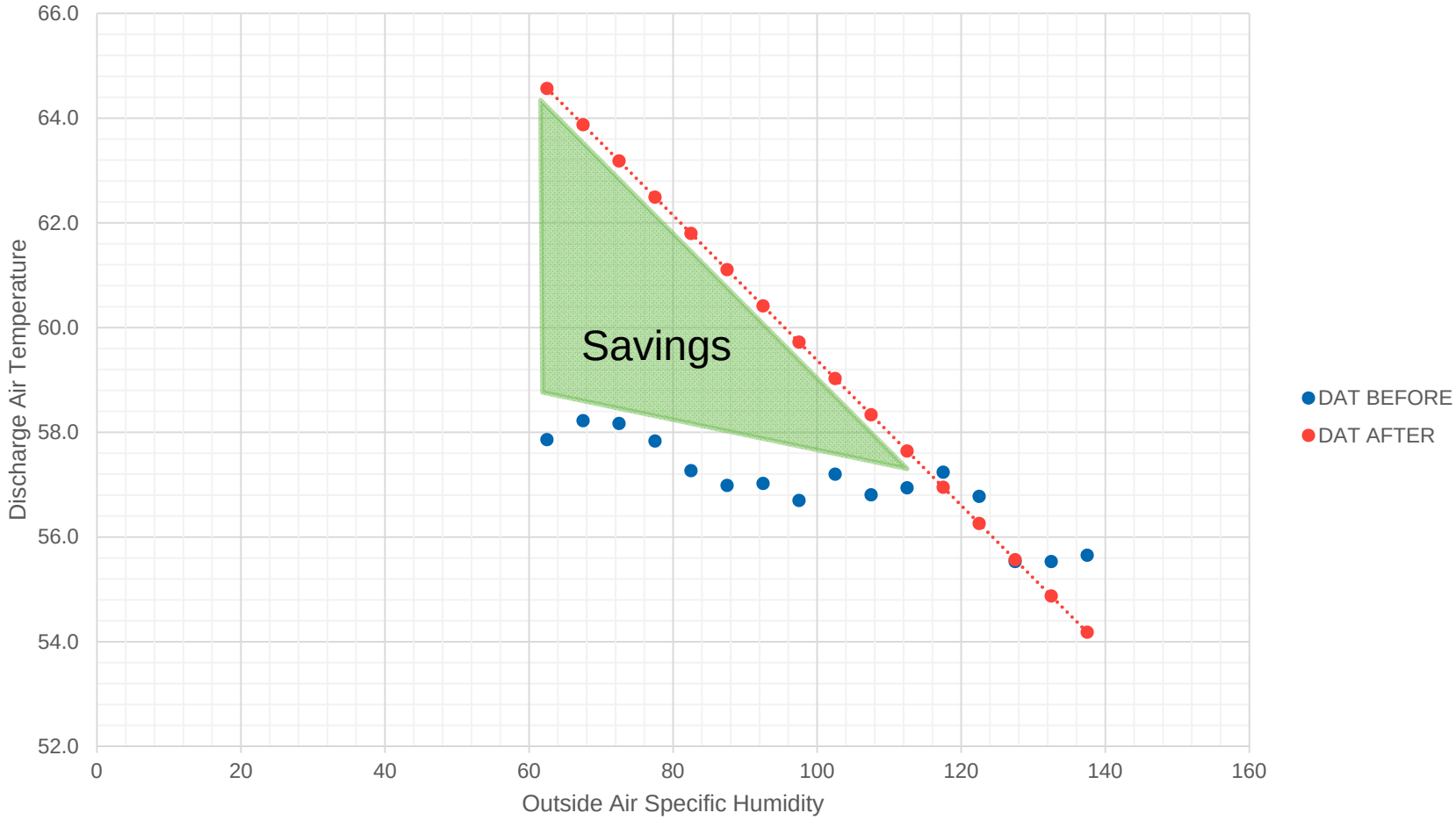


Development of Measures
Example Measures – DAT Reset + SP Reset

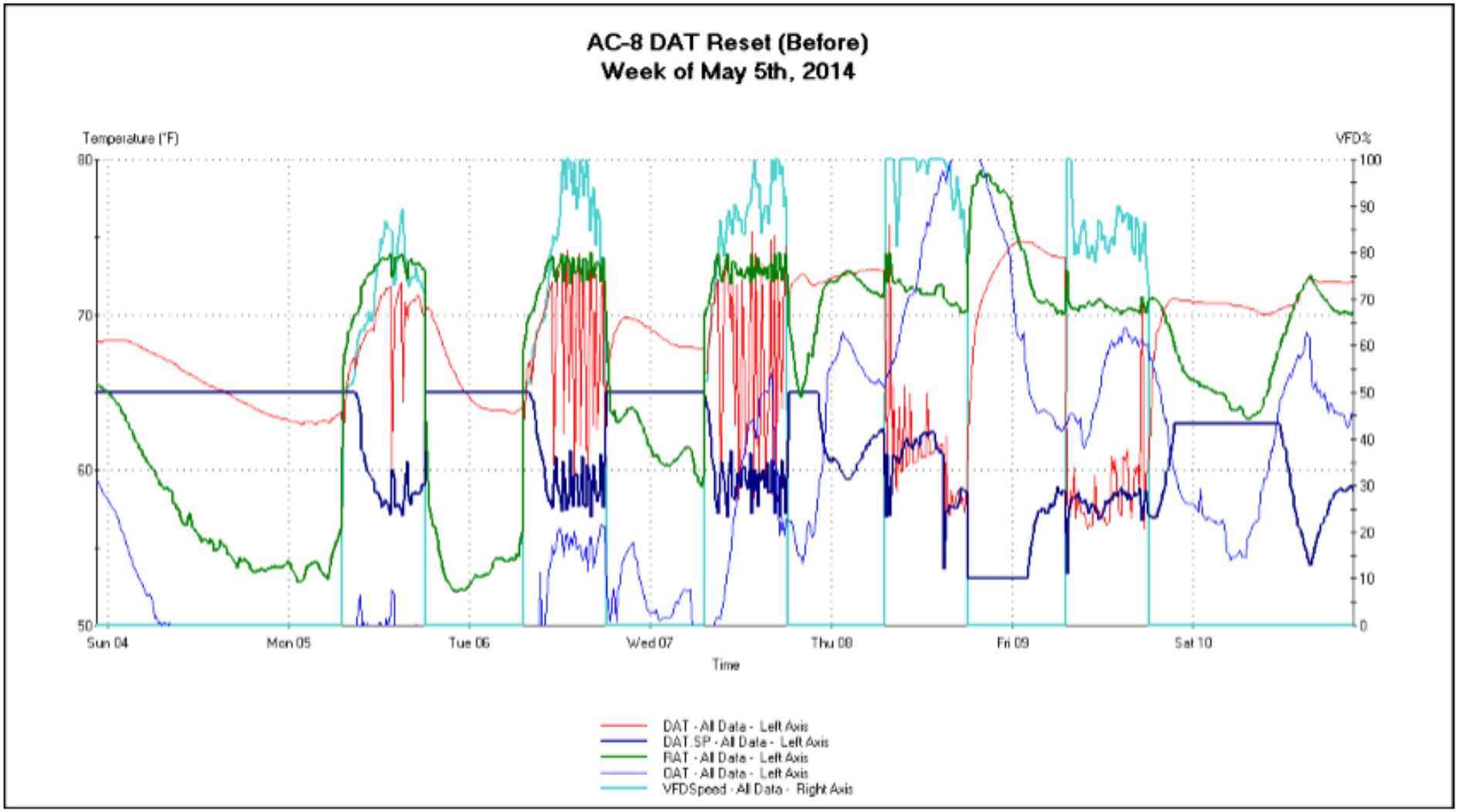
1. VAV Central Air Handlers with Perimeter FPBs
2. Linear DAT Reset Based on RAT
   - As RAT varies from 70-75°F, DAT varies from 65-55°F
   - Fans VFD speeds reach 100% prior to DAT reducing, causing hot calls
3. Fixed Static Pressure Set Point
   - Set based on worst case, and not changed
4. VAV and FPB Dampers Lack Positions Sensors
   - Cannot implement typical ASHRAE trim and respond sequence

Development of Measures
Example Measures – DAT Reset + SP Reset

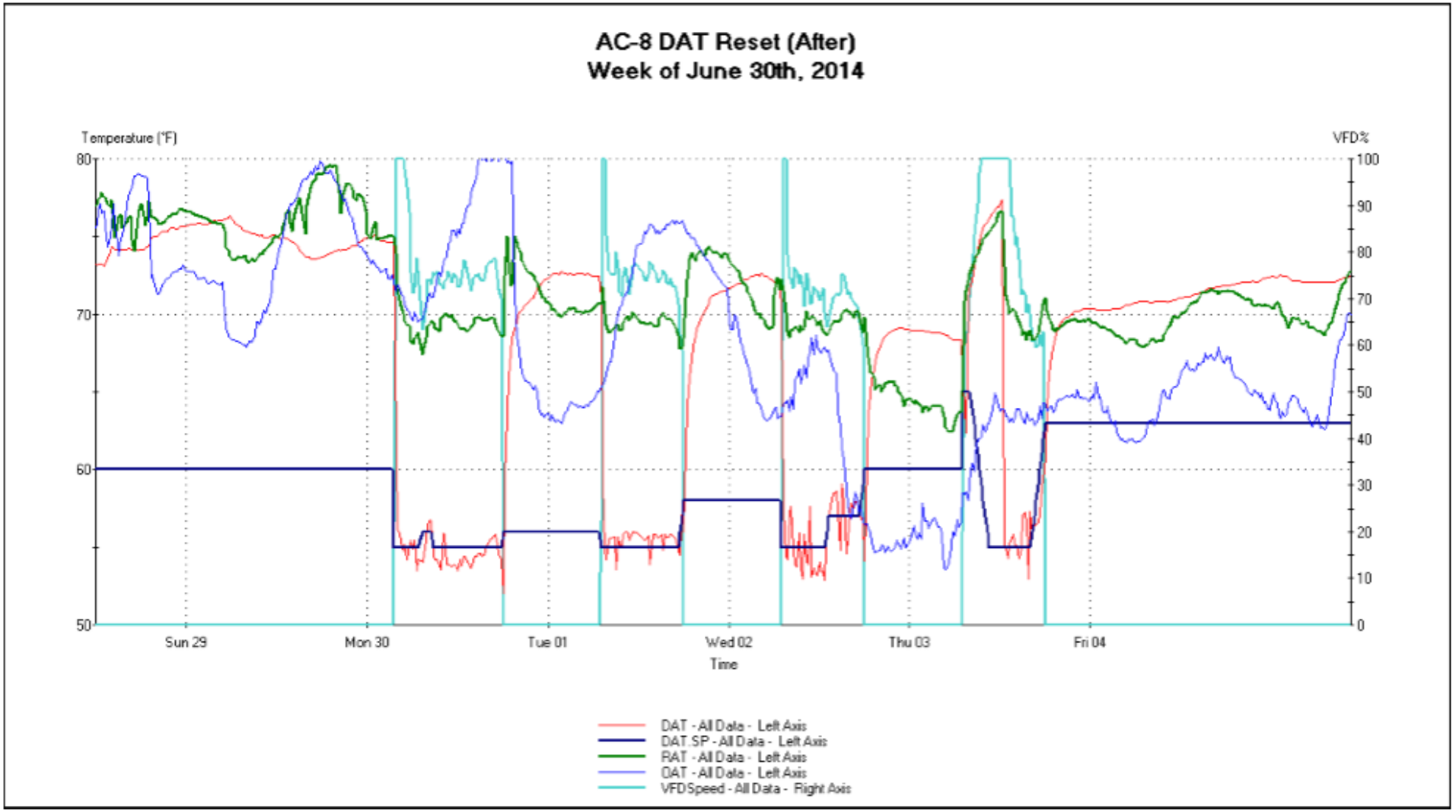
1. Revise DAT reset to reset based on VFD speed
   - As VFD% exceeds 65%, incrementally reset DAT lower

2. Static Reset Based on Box Airflow
   - If boxes can achieve flow set point, reset static lower
   - If boxes cannot achieve flow set point, reset static higher

Development of Measures
Example Measures – DAT Reset + SP Reset (Before)



Development of Measures
Example Measures – DAT Reset + SP Reset (After)



Low Cost Modifications
Items Usually Outside of RCx Scope

1. Controls Hardware Upgrades
   - While critical for RCx measures, may be too great of a payback to fall within RCx scope
2. VFDs
   - Best installed prior to RCx, so that programming can be revised as a part of RCx scope
3. Valves/Dampers
   - May prevent successful implementation of RCx measures, while still having a payback greater than 1.5 years
4. Equipment Replacement
   - Major equipment never part of RCx scope, and not “low cost”
   - Usually just become recommendations in RCx report

Low Cost Modifications
Items Within RCx Scope

1. Sensor Additions
   - Downstream static pressure sensors when VFD is present
   - Humidity sensors to allow condenser water reset, or airside economizer operation
2. Valves/Dampers
   - Usually outside of scope, but can be within scope under certain programs, and/or special situations where savings are substantial
3. Other with < 1.5 Year Payback

Verification & Persistence of Measures
How to Verify?

1. User Interface Verification
   - Most simple method of verification
   - Verify measure change is displayed
   - Only gives a go/no-go answer
2. Trend Data Verification
   - Most descriptive method of verification
   - Sometimes only practical method (time lapse critical)
   - Time lapse view allows 24/7 view of operational changes
   - Calculations easily performed with properly sorted before and after trend data
   - Before and after data can be used to verify implementation, and quantify savings

Verification & Persistence of Measures
How to Ensure Persistence?

1. User Adjustable Set Points?
   - May prevent sequence override
   - May increase operator confidence in BAS
   - May decrease ability to ensure measure persistence
2. User Ability to Override Sequences?
   - Should only be required when sequence is inadequately robust
   - Can be difficult to avoid, but generally results in reduced measure success
3. Are Operators Happy With Changes?
   - Critical to successful implementation
   - Must consider compromises as necessary
4. Education
   - If operators understand measures, user control is preferred
   - Operator training should always be a part of the completion of an RCx project

Verification & Persistence of Measures
How to Ensure Persistence?

1. Re-Commissioning
   - Verify continued measure functionality by performing functional tests
   - Should be a scheduled task for operators
2. Trend Data Revisit
   - Compare future trends to those used during measure development
3. Monitoring Based Commissioning (MBCx)
   - Still relatively uncommon, but growing
   - Variety of 3rd party software packages
   - Up front cost generally becomes cost prohibitive

Thank You!

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