COMMISSIONING FINDS AND SOLUTIONS

North Carolina State Construction Conference : March 26, 2015

PRESENTERS:

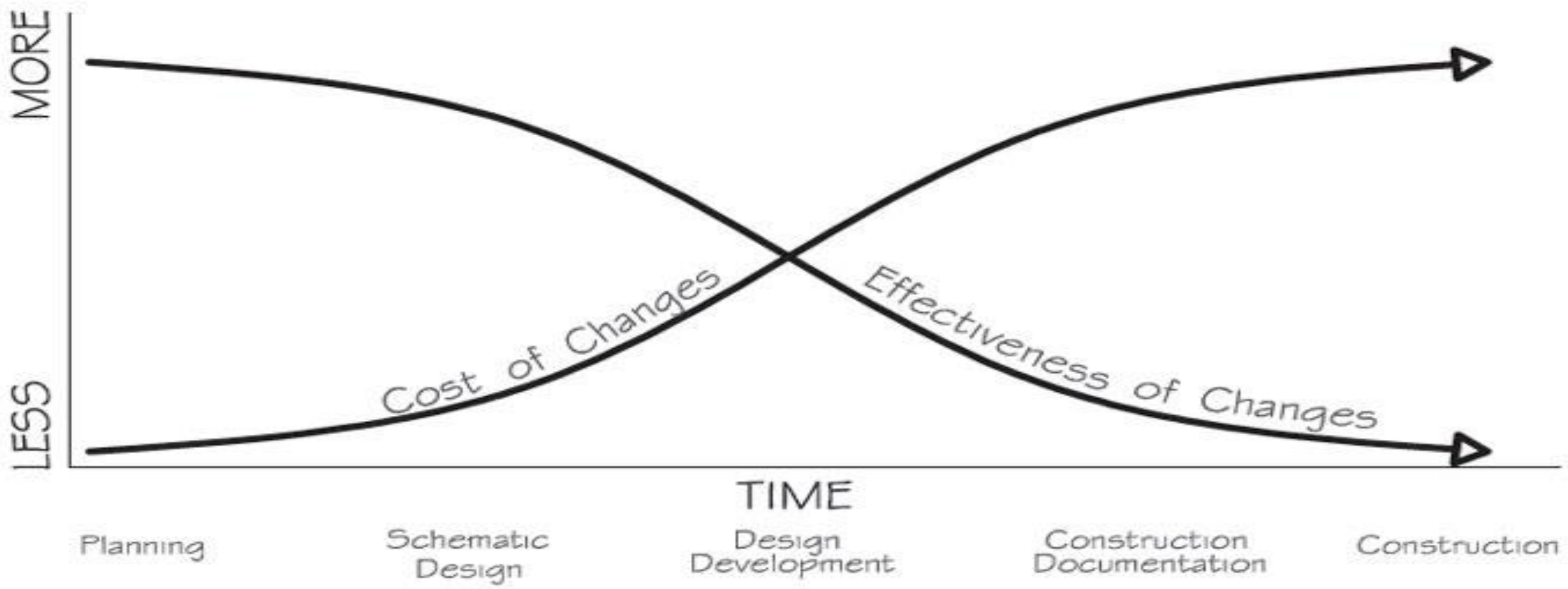
- **BARNEY YORK** / COMMISSIONING PRACTICE LEADER / **RMF**
- **MICHAEL CLICK** / COMMISSIONING PRACTICE LEADER / **AFFILIATED ENGINEERS, INC.**
- **KEVIN SHORT** / SENIOR COMMISSIONING ENGINEER / **FACILITY DYNAMICS**
- **ROD RABOLD** / COMMISSIONING COORDINATOR / ENGINEER / **UNC Chapel Hill**

COMMISSIONING FINDS AND SOLUTIONS
DESIGN PHASE

BARNEY YORK COMMISSIONING PRACTICE LEADER / **RMF**

START EARLY

INVOLVING A COMMISSIONING AGENT DURING THE EARLY PHASES OF A PROJECT'S DEVELOPMENT MAXIMIZES THE BENEFITS THAT COMMISSIONING AFFORDS AT THE HIGHEST POSSIBLE VALUE.



DESIGN PHASE

During the Design Phase, the CxA:

- Reviews the **Owner's Project Requirements**.
- Reviews the **Design Documents**.
- Develops **Commissioning Specifications**.
- Develops a Preliminary Commissioning **Plan**.
- Conducts a **Kickoff Meeting**.

So what usually goes wrong???

- OPR is not properly addressed
- Cx Specifications are not fully integrated
- Scope gaps are not identified or resolved
- Design comments not properly resolved


CHANGE ORDER

CHANGE THE FOLLOWING WORK TO THE ORIGINAL CONTRACT:

TOTAL PRICE

Payment to be made as follows:

ORIGINAL CONTRACT PRICE	$
CURRENT CONTRACT PRICE	$
REVISED CONTRACT PRICE	$

GENERAL CONTRACTOR | DATE

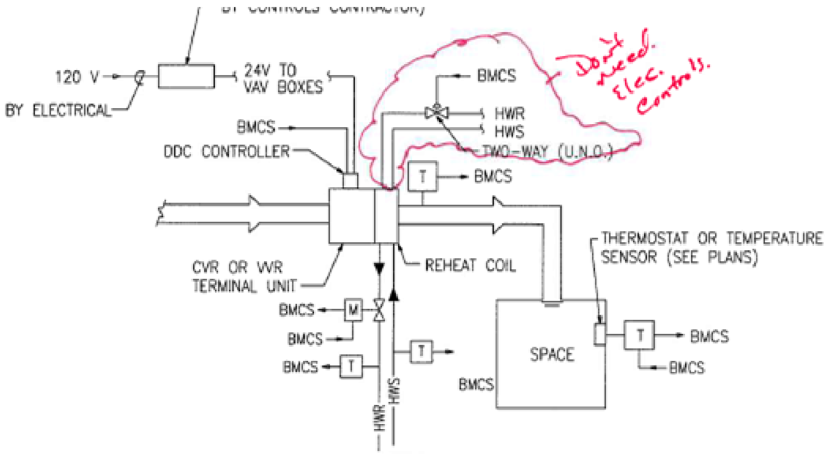
OWNER | DATE

Frequently Encountered OPR Issues

- Not established early – often an afterthought
- Lack of input from key stake-holders
- Not viewed as a critical document
- Unrealistic goals established
- Not comprehensive

Top Design Review Comments/Issues

- Controls Sequences not fully developed
- Uncoordinated Documents

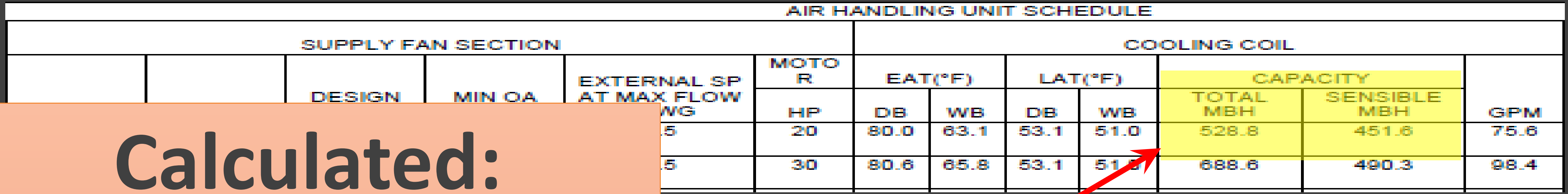


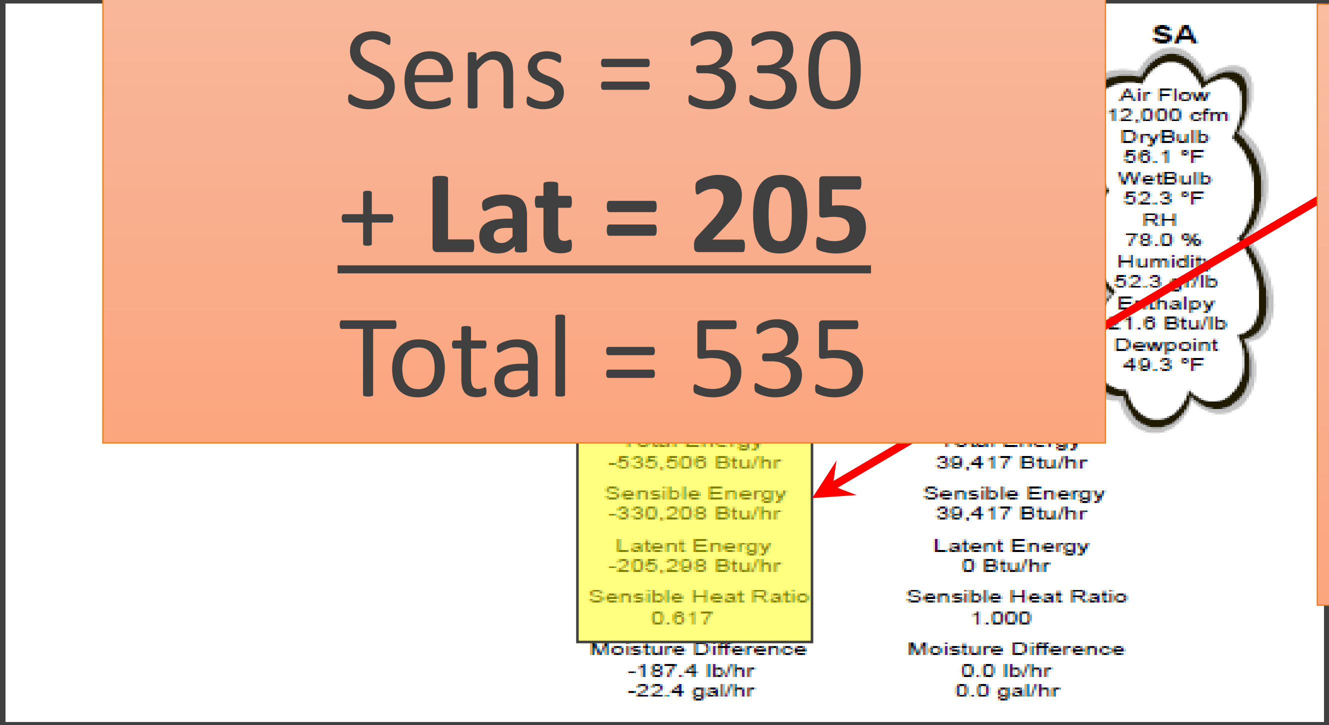
VVR & CVR TERMINAL UNITS

SYSTEM TYPE: TERMINAL UNITS WITH REHEAT

POINT DESCRIPTION	HARDWARE – OUTPUT FROM BMCS – DIGITAL	OUTPUT FROM BMCS – ANALOG: CONTROL POINT ADJUST	OUTPUT – ANALOG: POSITION	OUTPUT – ANALOG: FLOW LIMITS	INPUT TO BMCS – DIGITAL	INPUT TO BMCS – ANALOG: TEMP. °F	INPUT – ANALOG: FLOW	INPUT – ANALOG: POSITION	ALARMS – DIGITAL	ALARMS – ANALOG	SOFTWARE – APPLICATION PROGRAMS: SCHEDULED START/STOP	D.D.C.	TIMED OVER RIDE	REPORTS & LOGS	TREND LOGS	RUNTIME & MAINTAINANCE
GRAPHIC DISPLAY ●																
SPACE TEMPERATURE		●				●					●	●	●	●	●	●
CFM				●			●									
DAMPER ACTUATOR			●					●				●				
SUPPLY AIR		●				●					●					
HEATER WATER VALVE		●	●					●				●				
HEATING WATER SUPPLY						●										
HEATING WATER RETURN						●										

UNCOORDINATED DOCUMENTS





Calculated:

Sens = 330

+ Lat = 205

Total = 535

Scheduled:

Sens = 452

+ Lat = 77

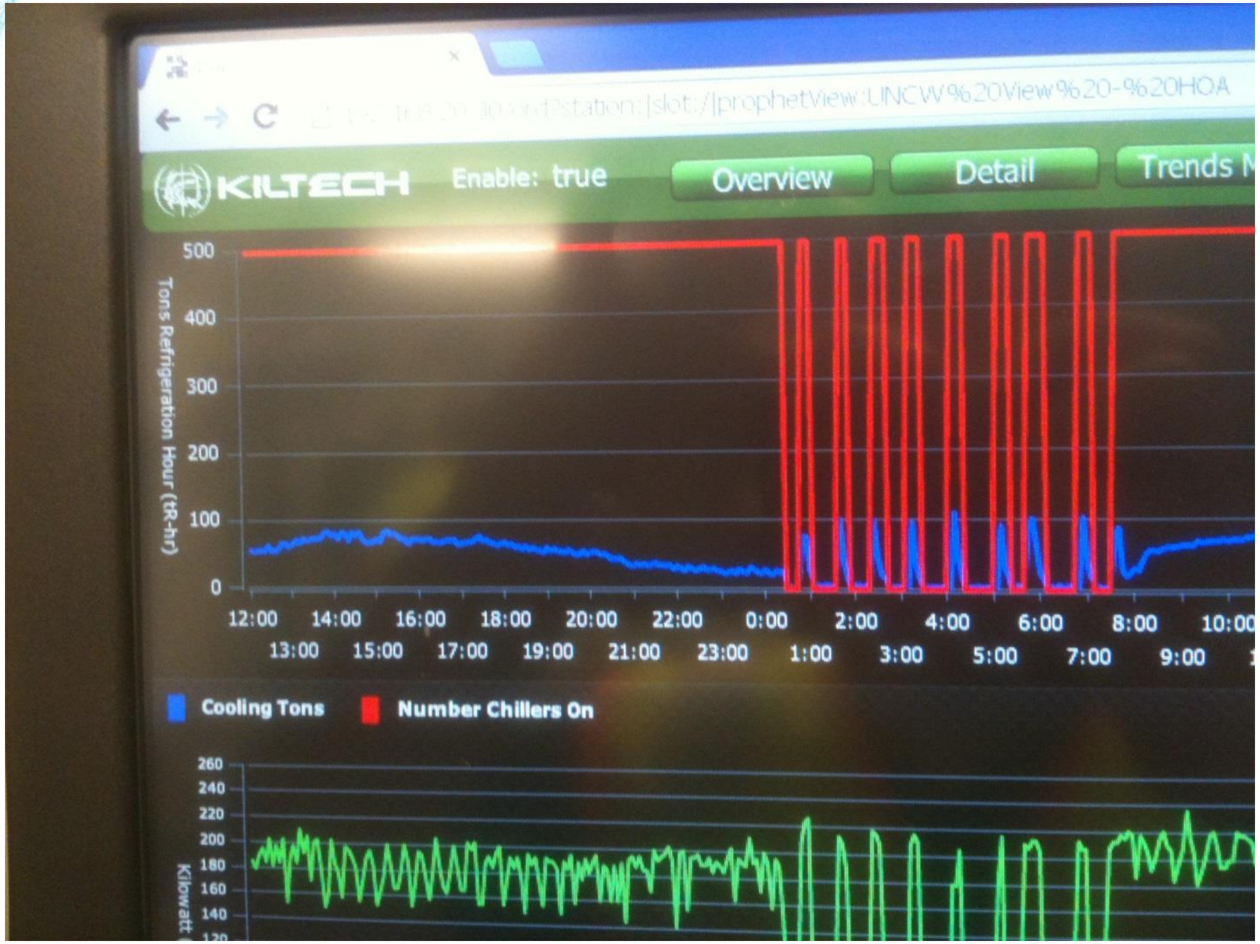
Total = 529

Top Design Review Comments/Issues

- Controls Sequences not fully developed
- Uncoordinated Documents
- **Oversized Equipment**

Oversized Equipment

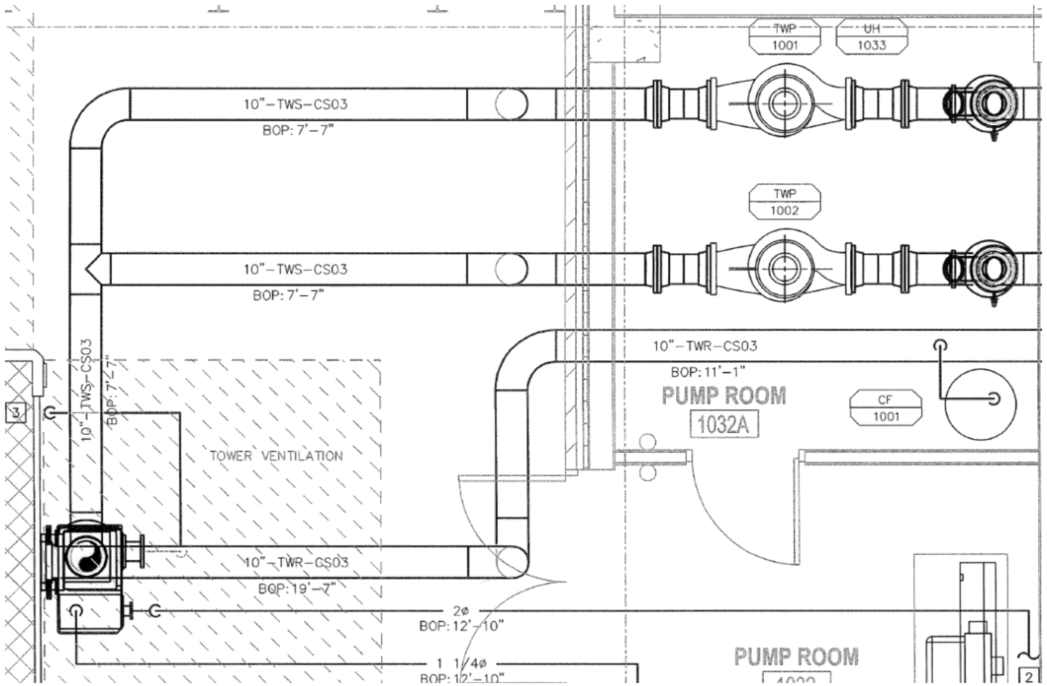
- Leads to software fixes for hardware issues!



- Oversized chiller questioned in the design
- Unable to turn-down once outside air is below 60°F
- Multiple start/stops
- Premature failures

Top Design Review Comments/Issues

- Controls Sequences not fully developed
- Uncoordinated Documents
- Oversized Equipment
- **Comments Not Properly Addressed Before Bid**



Improper Follow-through on Comments

Cx Agent Comment:

ID / Page/ Source	Name / Description and Recommendation A/E, CM, and Owner Response
M - 8	**Condenser Water Pipe Routing**
Dwg M-210, M-211 of DD Dwgs.	Is the condenser water pipe routing from the cooling tower to the pumps in the mechanical room such that the pipe rises higher than the basin of the tower? It's difficult to determine whether the piping is routed below grade or above grade on the drawings. If the routing is above grade, there is the potential for flow issues as the system is an open system.

Designer Response:

- M-7: Provisions have been made as required by code for this system.
- M-8: The pumps and piping have been revised since this comment was made and the piping does not rise above the basin of the tower.
- P-1: This system will be detailed in a schematic indicating the component features.

The Installation

Riser above basin
$12K Change order

So How Do These Things Happen???

Issue is with the process….

How to improve the process:

- Cx Agent must be more vocal and prioritize issues

Comments

ID / Page/ Source	Name / Description and Recom… A/E, CM, and Owner Respons…
General Comments	
GC - 4	**Lightning Protection** No Lightning Protection plans or d… AHJ.
Mechanical - HVAC	
M - 1	**Return Air Plenums** AHU-1,2,4,5,6: Large areas cover… to balance effectively. Excessive … outside or adjacent zones. For inst… return ducts into the zone with mul… room. Return fans should be used …
M - 2	**Mech room relief** Typical Mech rooms indicate open… damper, creating the mech room as… arrangement, and excessive pressu… Ducted relief air to the exterior lou…
M - 3	**Outside air quantities** AHU schedule M701 does not sho… makeup air, code ventilation, and …
M - 4	**Laundry make up air** AHU-4: verify adequate outside ai…
M - 5	**AHU-2 outside air and relief** AHU-2 shows no outside air or rel… connections and economizer opera…
M - 6	**AHU-3 Kitchen outside air** AHU-3 shows no outside air conne… connected.(MH110G)
M - 7	**Ductwork not readable** Ductwork on MH11MF and MH11…
M - 8	**AHU-6 return air** AHU-6 zone extends a very long d… also comment M-1). Consider a ne…

ID / Page/ Source	Name / Description and Recommendation A/E, CM, and Owner Response	Comment Status/ Type	Reviewer / Date Priority
M - 9	**24-hr HVAC zone** If infirmiry and security areas are 24-hr operation and differ from AHU-6 zone, consider new AHU and zone control for these areas. Will also resolve distance issue of previous comment.(MH112D and MH112F)	Open Design Concept	PJH, 2/20/2009 Review & Confirm Design Approach
M - 10	**AHU coil pull space** Recommend coil pull space be shown for all AHU's. Some do not appear to have adequate clearance.	Open Operational Maintenance / Service	PJH, 2/20/2009 Review & Confirm Design Approach
M - 11	**Filters** Some AHU zones indicate only 35% filters. Recommend minimum second bank of 65% filters for IAQ and dust control. (M701)	Open Design Concept	PJH, 2/20/2009 Review & Confirm Design Approach
M - 12	**Expansion Loops** Expansion loops needed on hot piping systems. (MP plan series)	Open Technical Issue	PJH, 2/20/2009 Review & Confirm Design Approach
M - 13	**Reverse return piping** Heating water piping includes long branch piping runs. Consider using reverse return on loops where feasible for better control and balancing.	Open Design Concept	PJH, 2/20/2009 Review & Confirm Design Approach
M - 14	**Specs needed** Mechanical specs division 23 needed: ductwork, air devices, CV and VAV reheat terminal units, exhaust fans, CRAC/ACCU, steam piping system	Open Project Completeness	PJH, 2/20/2009 Address within Next Submission
M - 15	**Larger Chilled Water Temperature Difference** Consider using a 14 degree temperature difference for the secondary chilled water system. This will permit smaller piping and pumps on the secondary resulting in lower energy usage. The primary system can remain at 10 degree difference as it is a constant flow system	Open Design Concept	BFY, 2/24/2009 Review & Confirm Design Approach
M - 16	**Equipment Sizes** The equipment sizes listed on the schematic diagrams and the mechanical schedules differ and are not consistent (850 ton chillers scheduled, 650 ton chiller schematic). Tower sizes are inconsistent as well. Need to coordinate to ensure appropriate pipe and electrical feeder sizes.	Open Project Completeness	BFY, 2/24/2009 Address within Next Submission
M - 17	**Primary Chilled Water Pump Manifold** Consider manifolding the primary pumps together to add redundancy for the system. This will allow for either pump to work with either chiller.	Open Alternative Consideration	BFY, 2/24/2009 Review & Confirm Design Approach
M - 18	**Cooling Tower Type** Specifications indicate that either a cross flow or a counterflow tower can be utilized. Designers should determine which is desired as the piping arrangements required vary on the type of tower selected. Typically counter flow towers are more efficient, but only a few manufacturers for this size and are more difficult to maintain. Cross flow towers are easier to maintain and usually more competitively bid.	Open Technical Issue	BFY, 2/25/2009 Review & Confirm Design Approach
M - 19	**Cooling Tower Design Temperature** The cooling tower wet bulb condition indicated on the schedule is 72 degrees. ASHRAE indicates that 78 or 79 degrees should be used for Raleigh NC. Too low of a wet bulb may result in an undersized tower.	Open Technical Issue	BFY, 2/25/2009 Address within Next Submission
M - 20	**Hydronic Boiler Schedule** Not enough information is provided on the hot water boiler schedule. Entering and Leaving Temperatures, water flow, pressure drop, electrical information etc. should be indicated to properly size the boiler.	Open Project Completeness	BFY, 2/25/2009 Address within Next Submission
M - 21	**Redundant Steam Boilers?** Are the steam boilers sized to be 100% redundant? If not, the feedwater system should be re-evaluated as it is currently sized for 3000 pph for a total load of 4000 pph. Code requires that the feedwater system be able to supply more than what the boilers can supply to prevent dry firing the boilers.	Open Design Concept	BFY, 2/25/2009 Review & Confirm Design Approach
M - 22	**Boiler Economizer Type** The boiler economizer should be specified as either a ASME Section I or… I is a higher construction standard and if not specified will probably resu…	Open	BFY, 2/25/2009

Page 6 of 16

How is someone to know what is important!

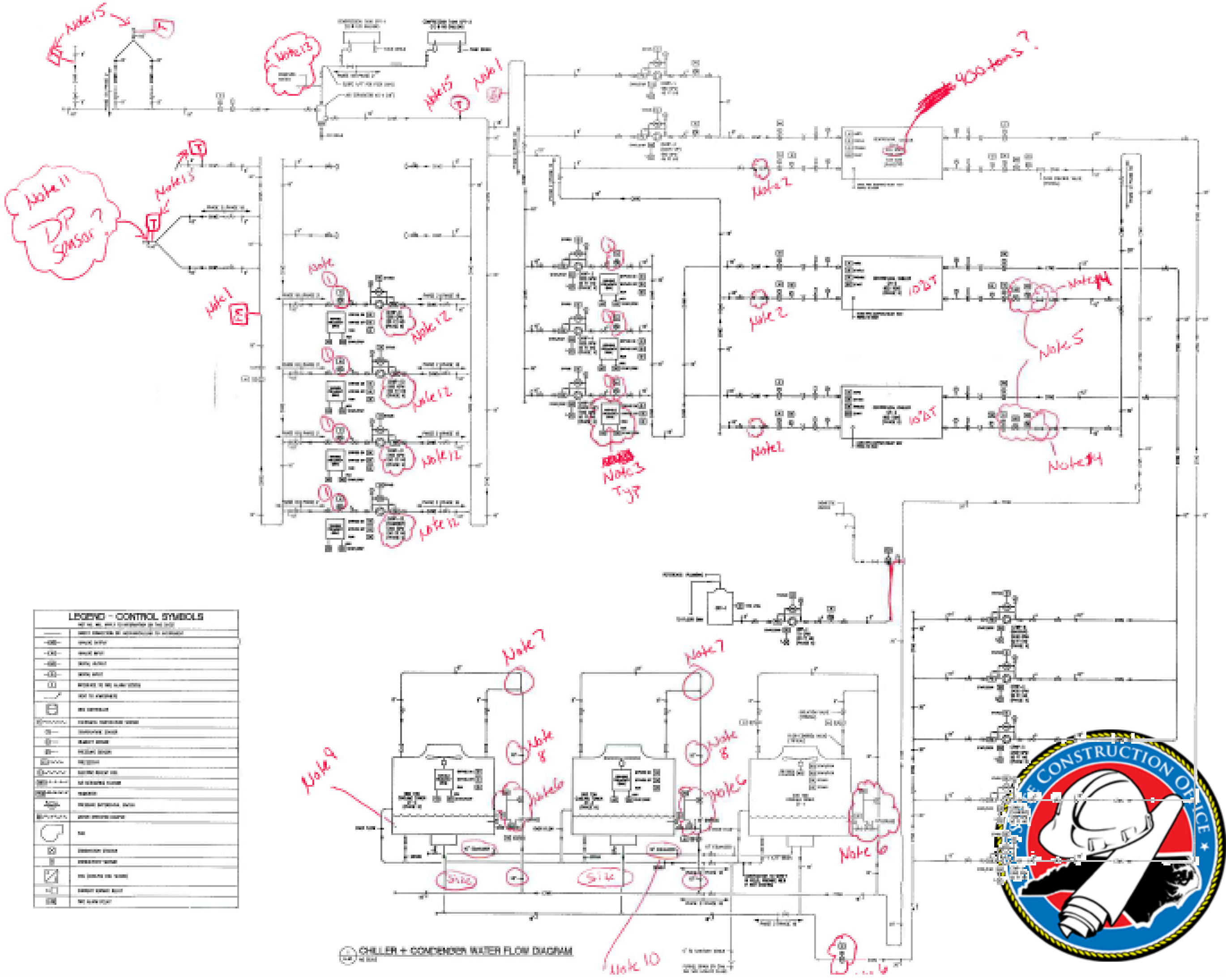
Everyone must listen for Key Alert Phrases:

- “Good enough for now…”
- “We can address it during the addendum”
- “Make sure we address during submittals”
- “Controls contractor will work it out”

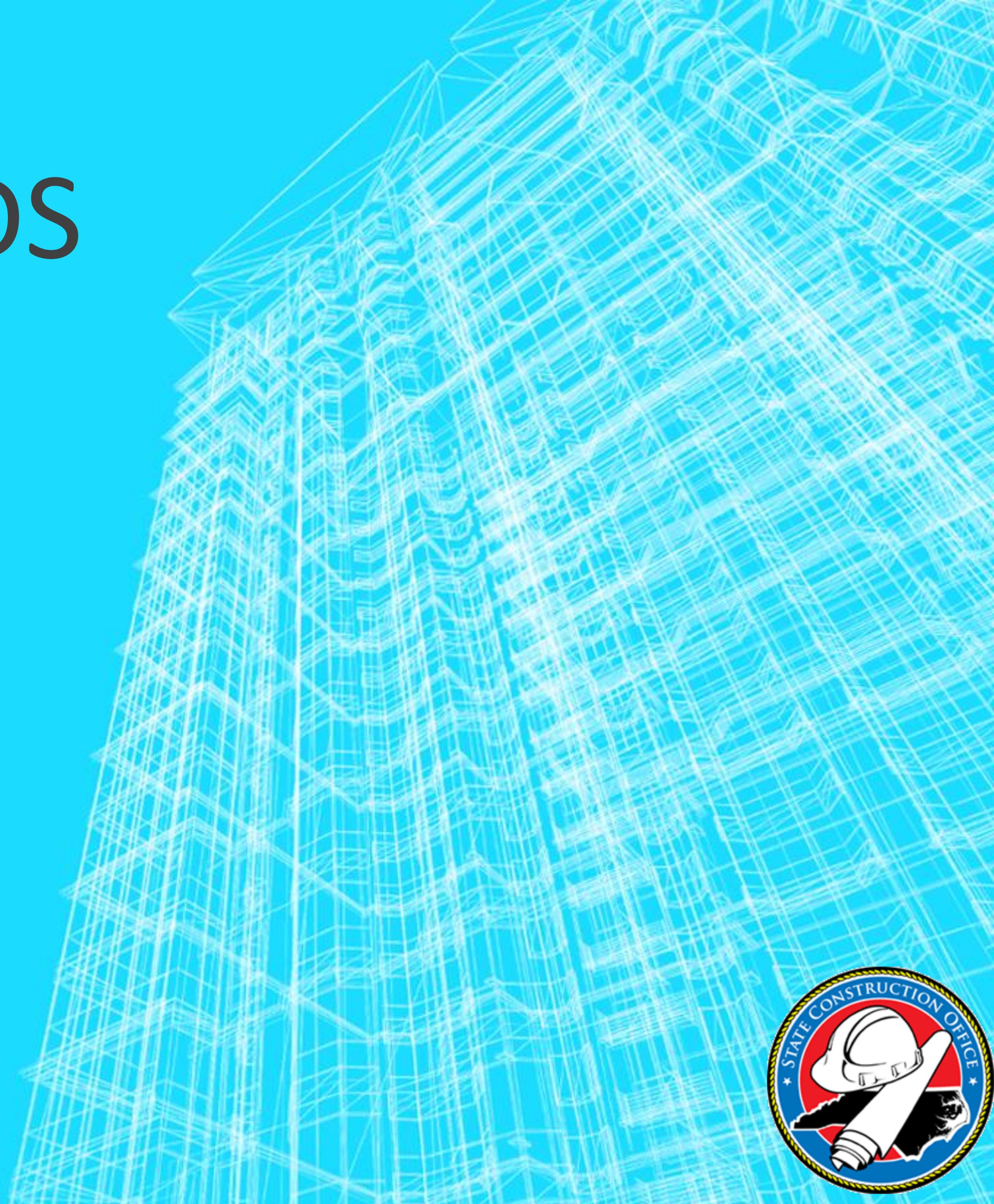
Owners must take an active stance – and not be passive!

Use the time and call a "working" meeting

- Builds relationship & Trust
- Fosters better understanding
- Mark up the drawings!



COMMISSIONING FINDS AND SOLUTIONS



MICHAEL CLICK COMMISSIONING PRACTICE LEADER / **AFFILIATED ENGINEERS, INC.**

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COMMISSIONING PROCESS: PROBLEMS AND SOLUTIONS
TRANSITION TO USER

Problem: Weak transition between project closeout and user ownership of the facility.

Solution: Systems Level training by the CxA that includes User, Facilities, Designer to review system operations. Included training documentation in a detailed systems manual.

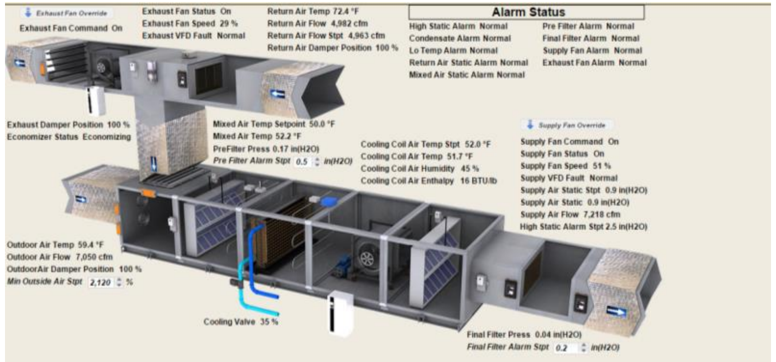
COMMISSIONING PROCESS: PROBLEMS AND SOLUTIONS
ENERGY METERS

Problem: Redundant and missing meters throughout projects.

Solution: Commissioning Agent generated metering plan

COMMISSIONING PROCESS: PROBLEMS AND SOLUTIONS

BAS INTEGRATION



Problem: BAS Integration Oversight

Solution:

- Requested clarification of owner/designer-desired points for integration during design phase.
- Led team-oriented BAS Integration meetings with vendors and verified point accuracy during functional testing/construction phase.
- Recommended trend parameters for detailed logging of data for review during warranty/acceptance phase.

ACCEPTANCE PHASE COMMISSIONING / FUNCTIONAL PERFORMANCE TESTING

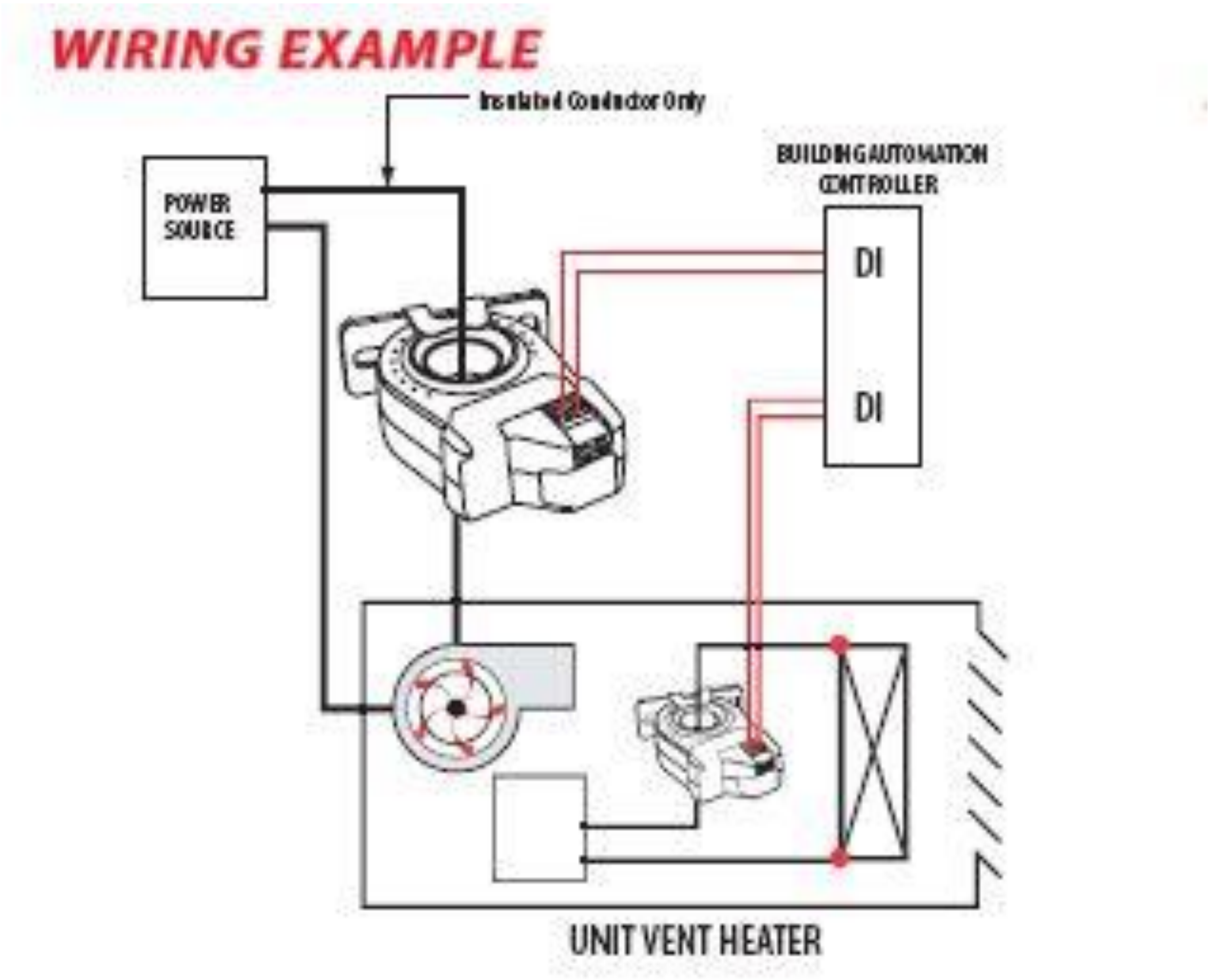
Case Study Examples of how Function Performance Testing has uncovered and then resolved problems with HVAC Systems

Kevin Shortt, PE – Facility Dynamics Engineering

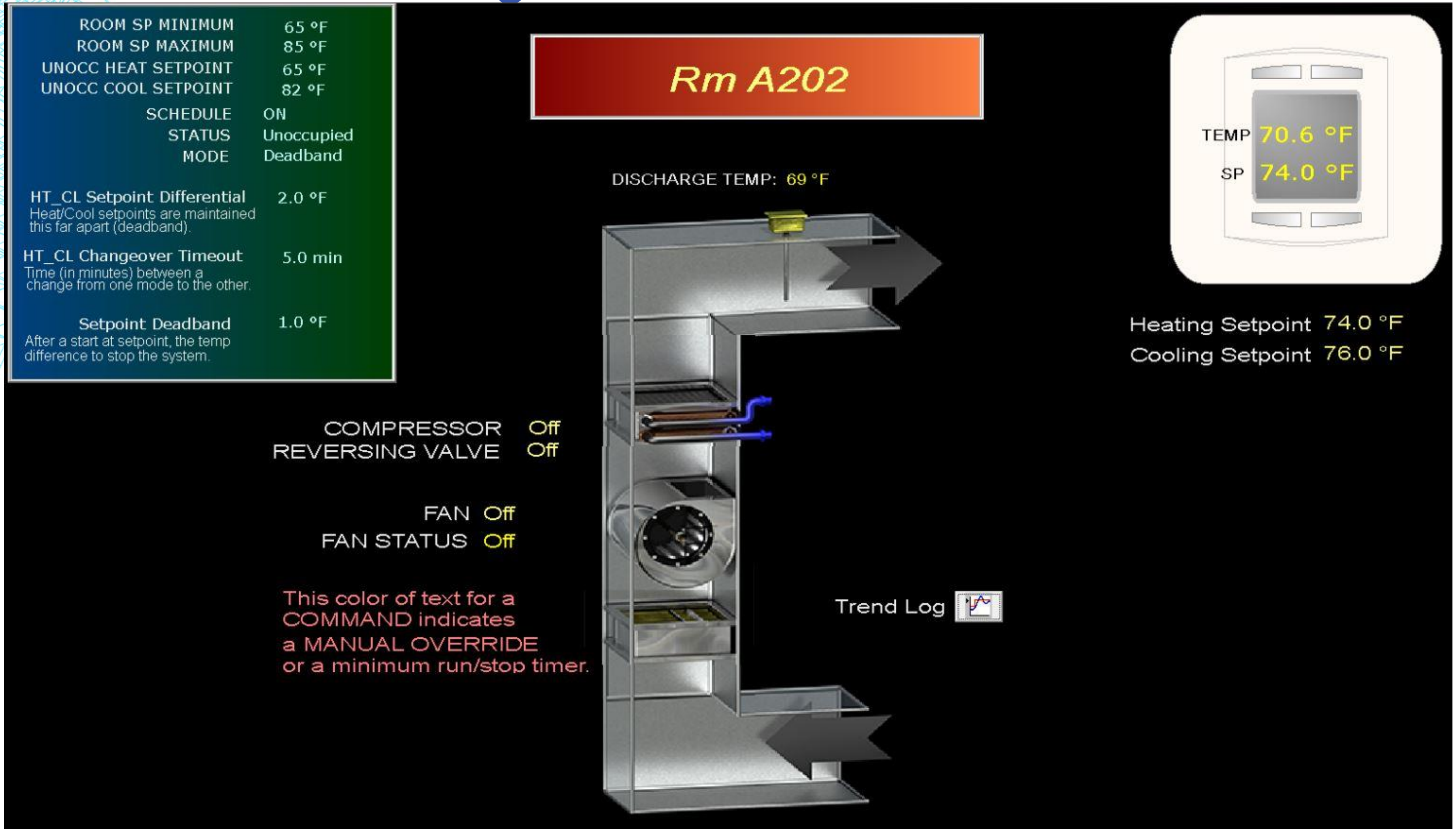
Case Study:
Application of a Fan Status Current Switch

- Current switches are utilized to prove status of a Motor, etc. by detecting amperage draw to the motor windings
- When the amperage draw fall below a specific level, the status of the device is assessed as “OFF”.
- When the amperage draw rises above a specific level, the status of the device is assessed as “ON”
- By comparing the commanded output to the feedback status, the BAS is able to prove that a motor is actually operating rather than just assuming that it is.

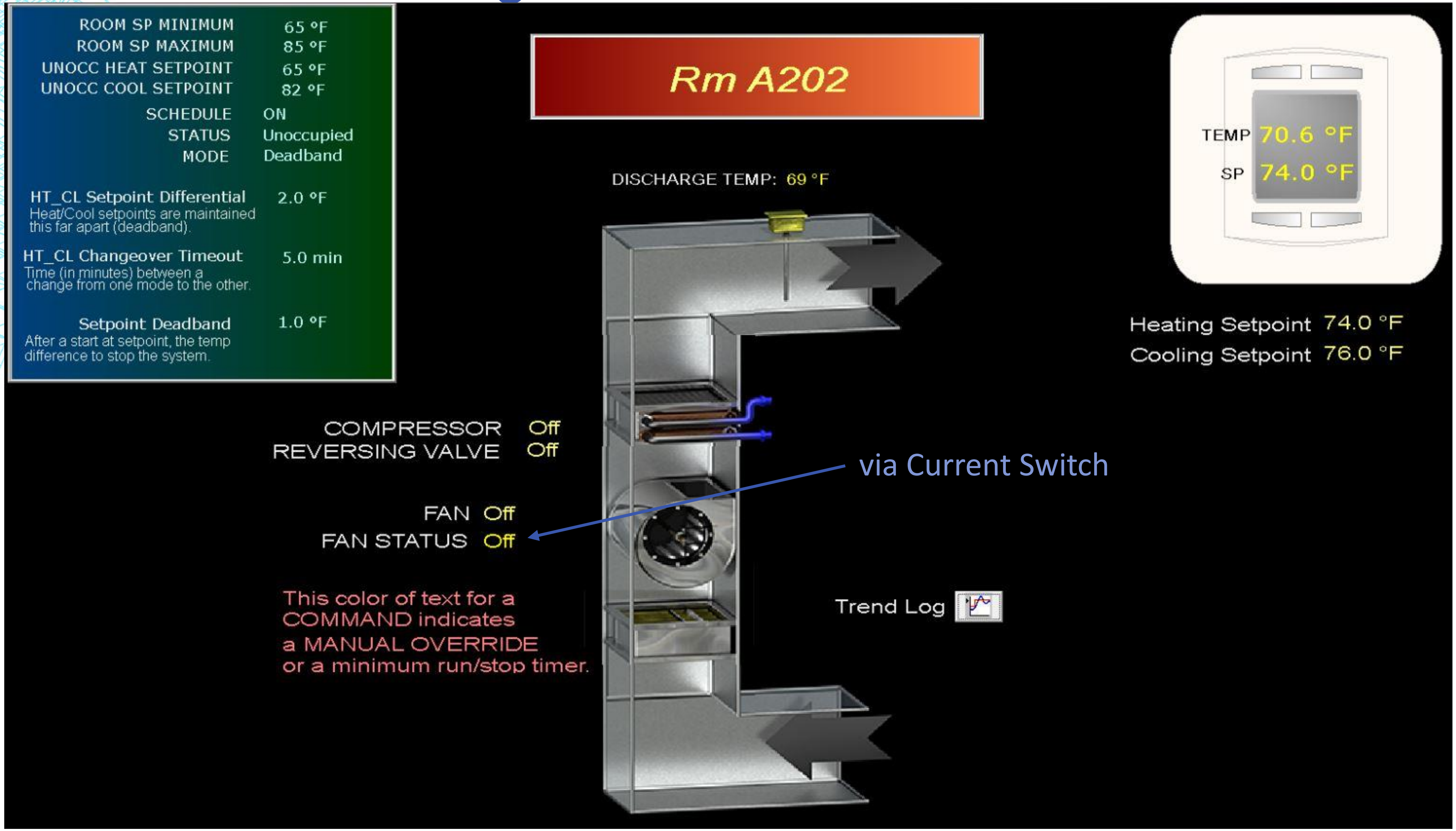
Case Study:
Application of a Fan Status Current Switch



Example of a Water Source Heat Pump with Fan Status being monitored

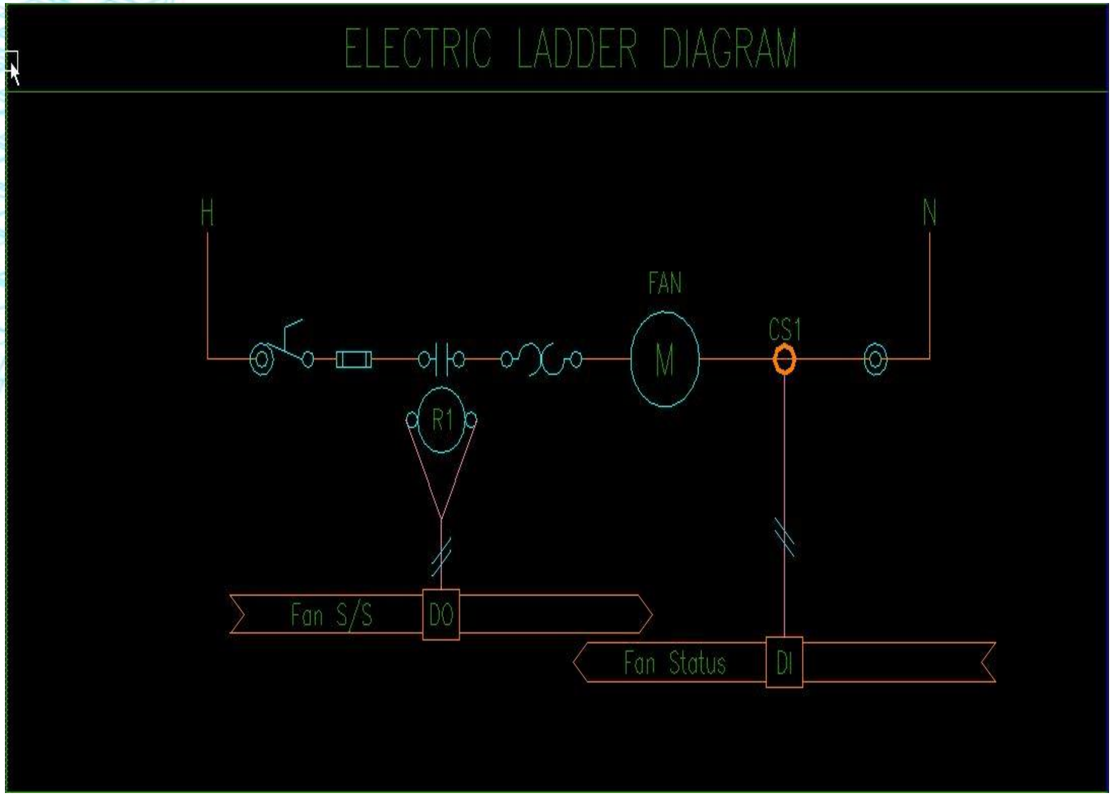


Example of a Water Source Heat Pump with Fan Status being monitored

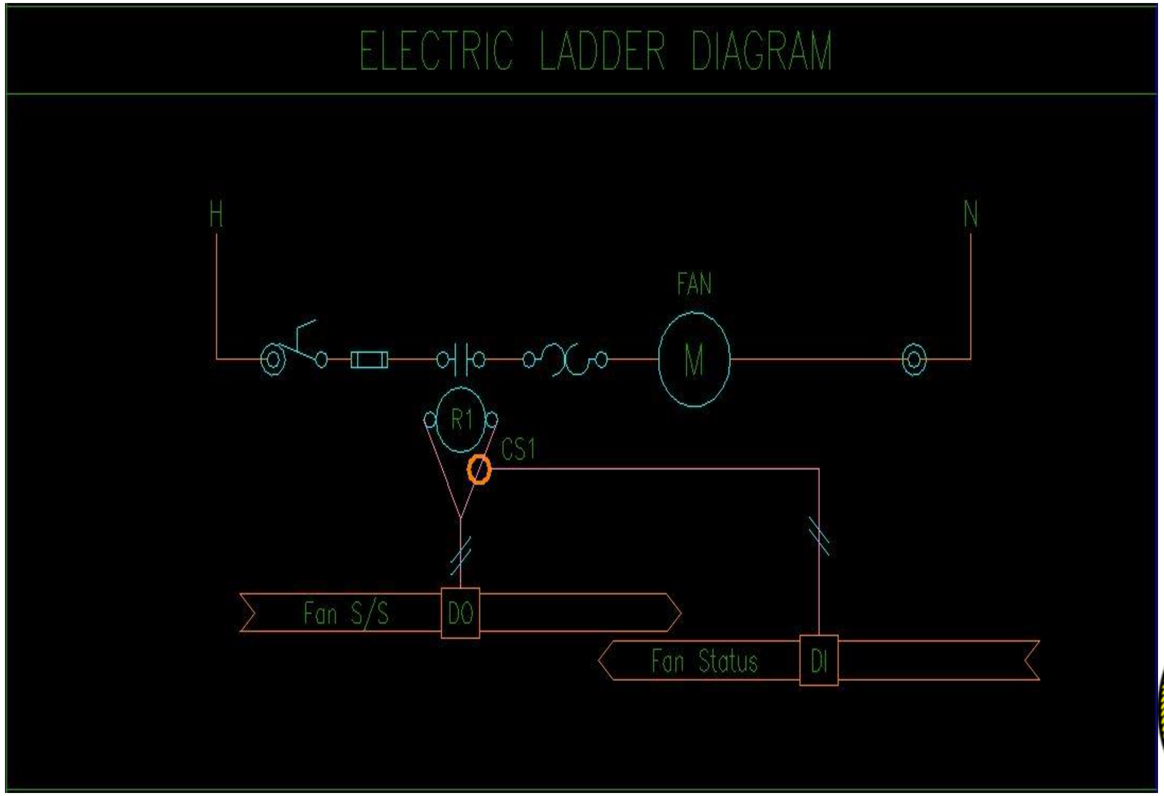


Fan Enable/Status Wiring Diagram

Design Intent



What the Contractor Installed



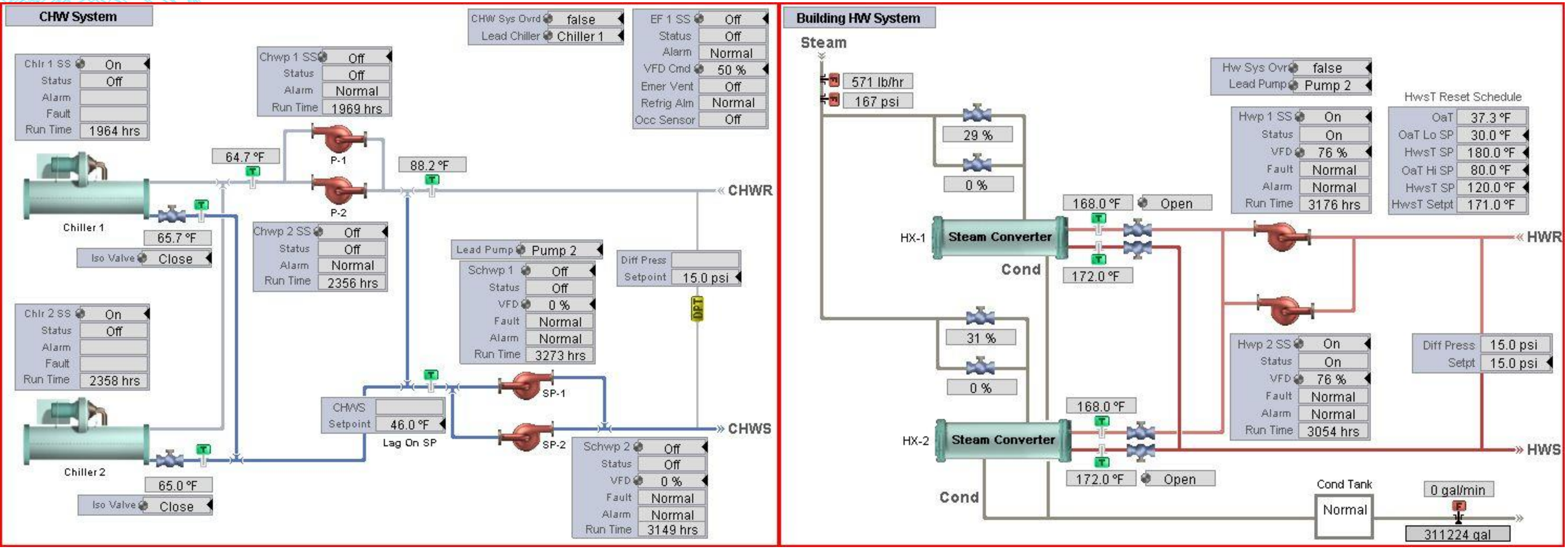
Conclusions:
Fan Status Current Switch Installation

- By installing the current switch across the coil of the command relay, the contractor was simply indicating the status of the relay – NOT the fan.
- Classic instance of contractor taking the “easier” path.
- Installing the current switch around the motor power feed meant that they would have to disconnect the motor wiring, feed it through the current switch and then reconnect the wiring. This was the correct procedure.
- During the commissioning process, this issues was caught and corrected. Issue would likely not have ever been noticed by the Owner.

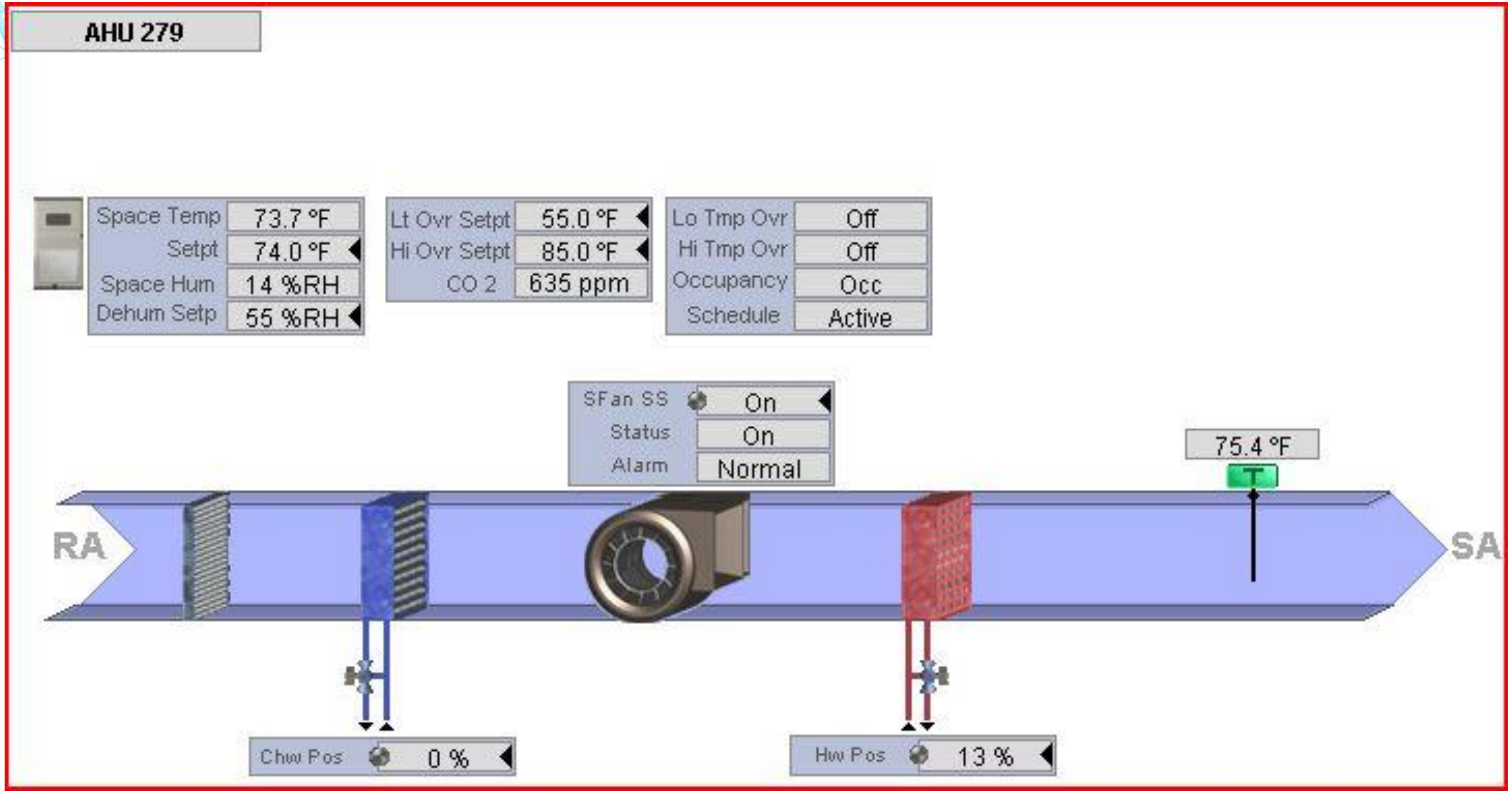
Case Study: Heating Water / Chilled Water Crossed Piping

- Initial Symptom of the Problem: Chilled Water temperatures were often in the 110°F range
- Classic "Difficult to Find" problem. During normal operating conditions, the issue was not noticed or ever detected.
- A review of trends discovered the problem at night (when no one was on site) when the Outside Air temperatures dropped and the Chilled Water System was disabled.
- Initial analysis was that some piping had been cross connected. Contractor did not agree with assessment – correction of the problem would be difficult to find.

Schematic View of ChW & HW Systems

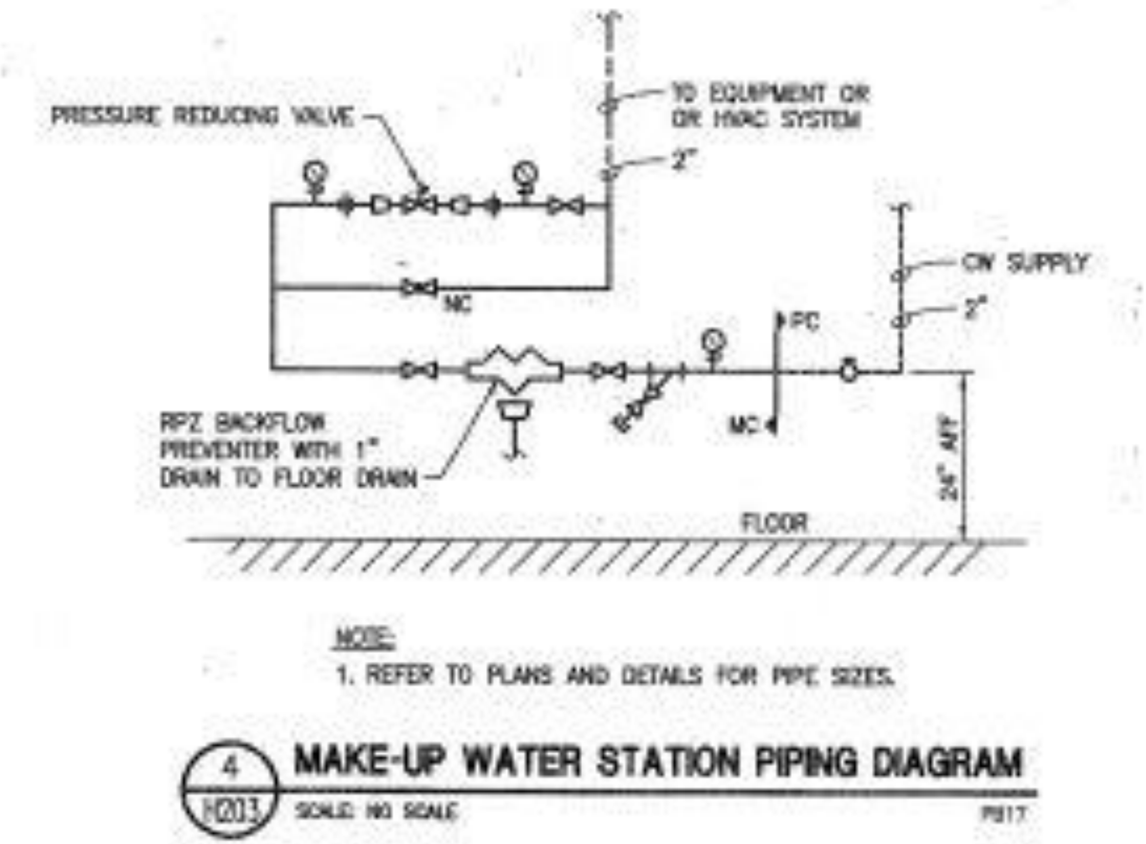


Typical AHU/FCU on project



Conclusion – Crossed Pipe System

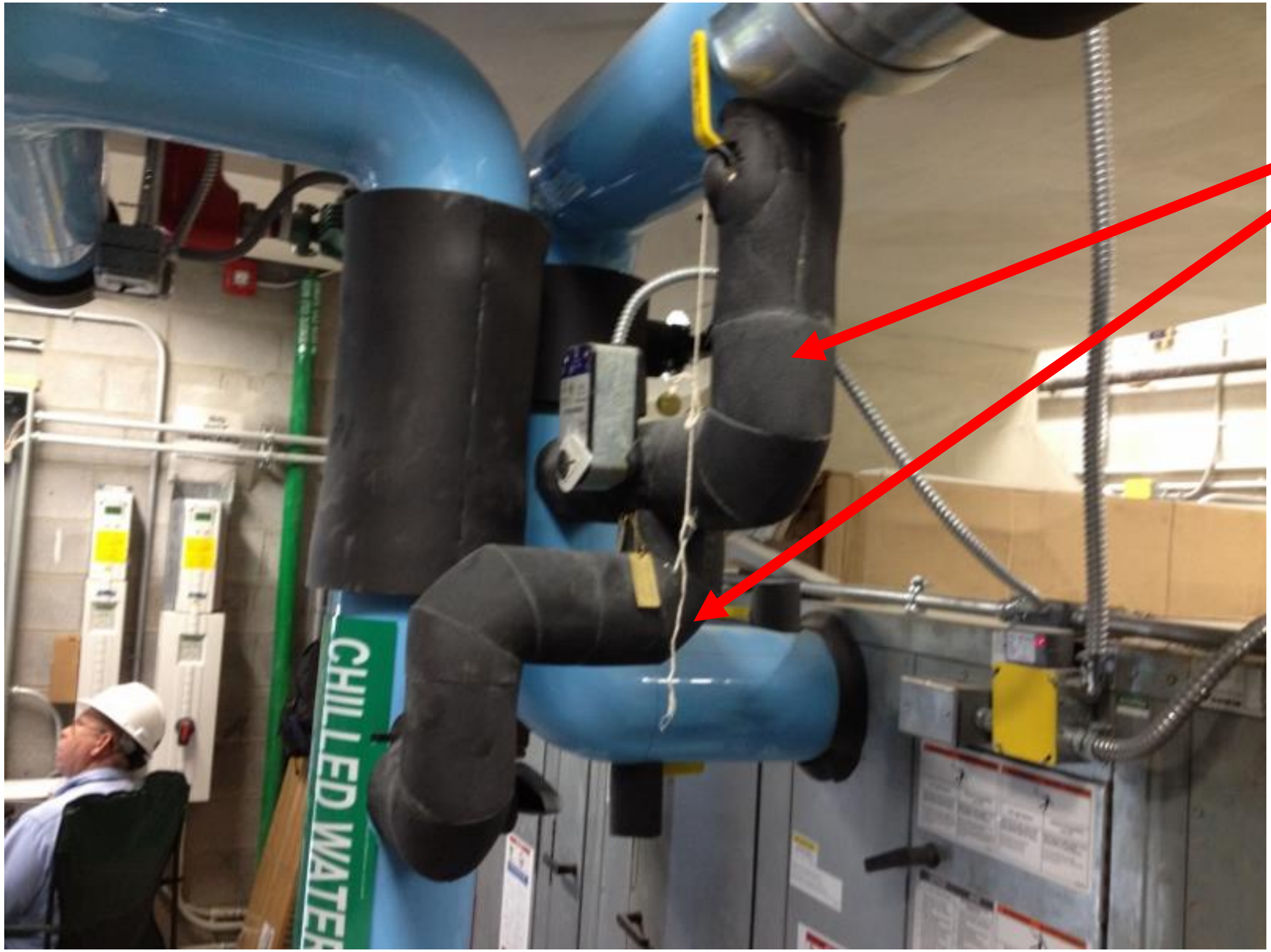
- To prove the cross connection existed, the fill stations on both systems were isolated and all pumps were commanded OFF. Then the Chilled water was drained slowly from the system.
- We observed that the pressure for both systems dropped – Proving the systems were connected.
- Contractor finally relented and searched riser by riser / fan coil by fan coil until they finally corrected all of the crossed connections.
- Relative Energy Savings related to this issue was enormous.



Case Study: Chilled Water Coil Flow

- System was a constant volume chilled water flow system. Only major connected load was a single AHU that served the entire building. There were also a few small fan coil units (insignificant flow compared to the AHU)
- TAB report of the chilled water flow indicated that proper flow was confirmed at the chiller.
- Through functional testing of the systems, it was found that the only way to achieve acceptable flow through the chiller was to open a line sized bypass valve around the control valve.

Chilled Water Coil Piping



- Take-Off piping was same size as the valve - should have been line sized up to the control valve.
- Multiple 90°s in the piping exacerbated the issue.
- Excessive pressure drop was observed and proven.

Conclusion: Chilled Water Coil Flow

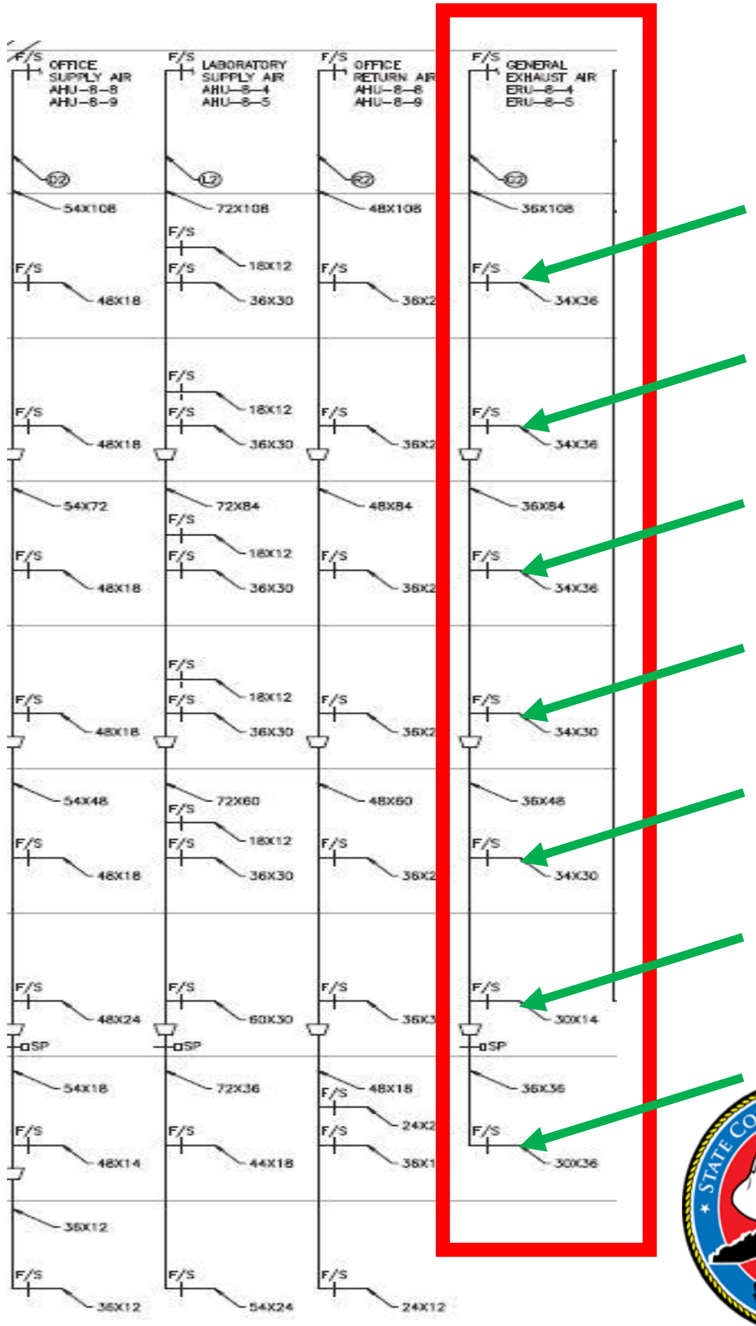
- Able to calculate and also verify that the pressure drop through the control valve piping was excessive.
- Through functional testing of the systems, it was found that the only way to achieve acceptable flow through the chiller was to open a line sized bypass valve around the control valve.
- Contractor finally agreed that there was an issue and agreed to fix the problem by upsizing the branch piping up to the valve.
- Retesting (in conjunction with the TAB contractor) revealed that adequate flow now existing without utilizing the bypass around the AHU coil

Case Study: Duct Leakage

- A typical system of General Exhaust ductwork with branch ducting mains to each 7 floors in a particular building.

- TAB report revealed the unit was producing sufficient exhaust flow.

- TAB report also revealed the terminal units were satisfied and able to meet setpoints.



Case Study: Duct Leakage

- During functional testing it was determined that when an entire floor (or floors) was forced into full cooling (maximum flow), the exhaust terminals could not meet setpoint (dampers at 100% open). Diversity should not have been a factor.
- Subsequent traverses also revealed significant differences between readings taken at main branch ducts and total flows to/from the exhaust terminal units

$$\begin{array}{r} 2 \\ \underline{+2} \\ =3 \end{array}$$

Conclusion: Duct Leakage

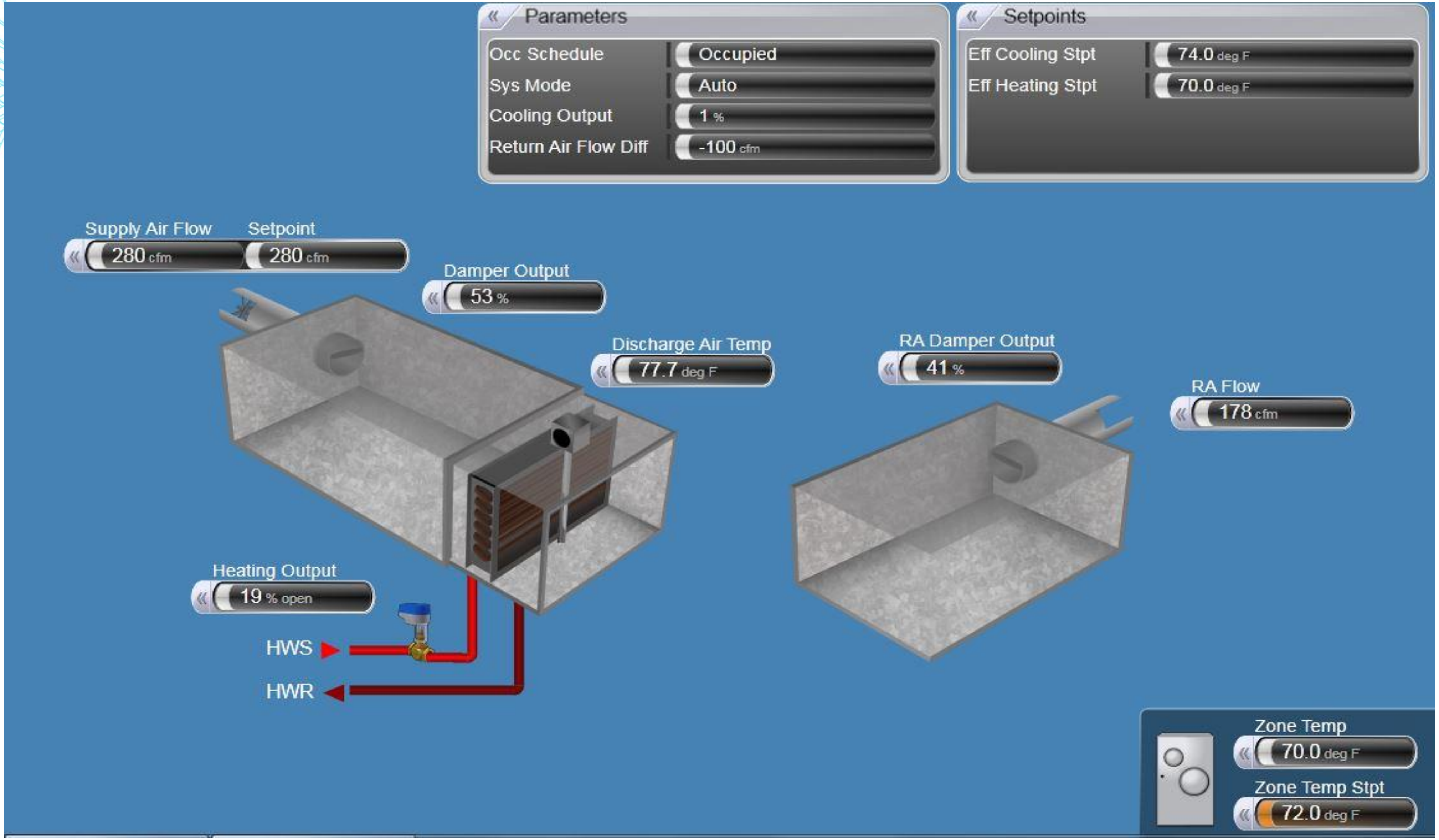
- By working directly with the TAB and Mechanical Contractors, we were able to find and then prove that the problem existed.

- Mechanical contractor was then mandated to remove ceiling tiles and re-seal all the medium pressure ductwork

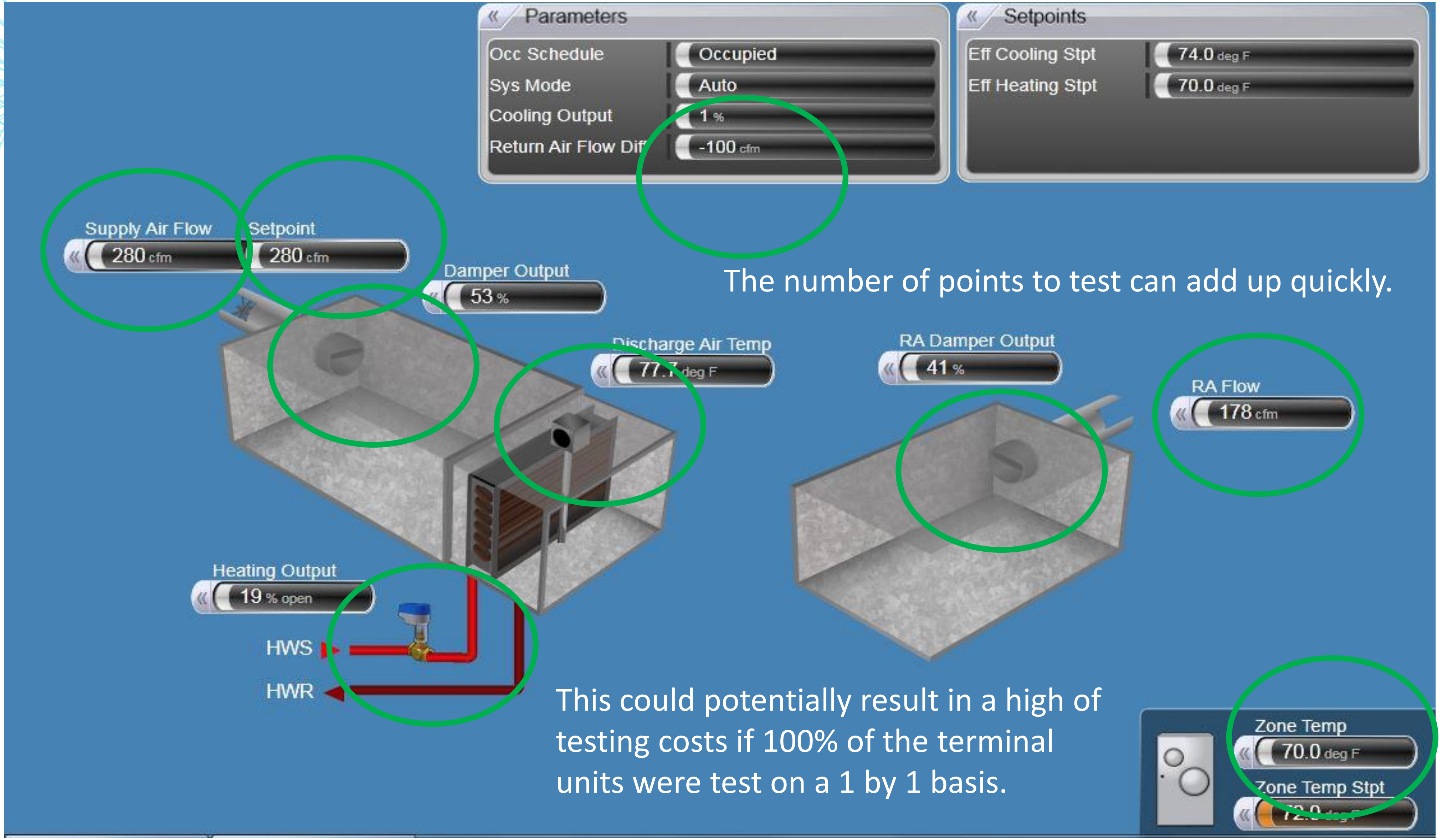
Case Study: Terminal Unit Testing

- Terminal unit testing is typically performed via a sampling method due to the large quantities that are typically in a single building.
- While this does provide some information regarding statistical error, it typically will not always find all (or even the majority) of the problems that may exist.
- In lieu of taking a sample of the terminal units and functionally testing each of those units top to bottom – better results can be found by testing nearly 100% of the terminal units via the BAS (Heating Mode, Cooling Mode, Damper Operation, Fan operation, etc.) and running statistical analysis. Then, a small sample can be physically tested at each of the units.
- For example, a typical zone with a Supply and Exhaust VAV terminal:

Zone with Supply/Exhaust terminals



Zone with Supply/Exhaust terminals



The number of points to test can add up quickly.

This could potentially result in a high of testing costs if 100% of the terminal units were test on a 1 by 1 basis.

Terminal Unit Testing – BAS Report Example

Tailored Summary | Summary

Available Tailored Summaries

- BT1 Floor 2 VAV Sup
- BT1 Floor 2 VAV Ret

Key Data

Item	Value
BT1.ROOF.AHU-R-1.DA-T	61.7 deg F
BT1.ROOF.AHU-R-2.DA-T	55.0 deg F
SHWS-T	146.7 deg F
HWS-T-SP	180.0 deg F

BT1 Floor 2 VAV Supply Box	ZN-T	ZNT-SP	DA-T	HTG-O	SAF-SP	SA-F	DPR-O
BT1.LEVEL 2.ATS-1-2-1 (Nurse Manager Office 22010 (BT1-AHU-R-1))	69.9 deg F	72.8 deg F	88.1 deg F	49 % open	100 cfm	100 cfm	33 %
BT1.LEVEL 2.ATS-1-2-2 (Phys Workroom 22009 (BT1-AHU-R-1))	70.1 deg F	69.2 deg F	65.7 deg F	0 % open	300 cfm	298 cfm	44 %
BT1.LEVEL 2.ATS-1-2-3 (Patient Room 22008 (BT1-AHU-R-1))	70.1 deg F	68.4 deg F	64.3 deg F	0 % open	280 cfm	280 cfm	39 %
BT1.LEVEL 2.ATS-1-2-4 (Patient Room 22007 (BT1-AHU-R-1))	70.0 deg F	68.0 deg F	71.1 deg F	0 % open	280 cfm	279 cfm	52 %
BT1.LEVEL 2.ATS-1-2-5 (Patient Room 22006 (BT1-AHU-R-1))	70.1 deg F	71.2 deg F	77.1 deg F	0 % open	280 cfm	281 cfm	45 %
BT1.LEVEL 2.ATS-1-2-6 (Patient Room 22005 (BT1-AHU-R-1))	70.1 deg F	69.8 deg F	74.1 deg F	0 % open	280 cfm	277 cfm	40 %
BT1.LEVEL 2.ATS-1-2-7 (Patient Room 22004 (BT1-AHU-R-1))	70.0 deg F	68.0 deg F	62.8 deg F	0 % open	280 cfm	277 cfm	46 %
BT1.LEVEL 2.ATS-1-2-8 (Patient Room 22003 (BT1-AHU-R-1))	70.0 deg F	68.0 deg F	70.0 deg F	0 % open	280 cfm	281 cfm	40 %
BT1.LEVEL 2.ATS-1-2-9 (Patient Room 22002 (BT1-AHU-R-1))	70.0 deg F	73.2 deg F	97.9 deg F	59 % open	280 cfm	276 cfm	45 %
BT1.LEVEL 2.ATS-1-2-10 (Patient Room 22001 (BT1-AHU-R-1))	69.8 deg F	70.8 deg F	63.2 deg F	0 % open	280 cfm	283 cfm	43 %
BT1.LEVEL 2.ATS-1-2-11 (Patient Room 21008 (BT1-AHU-R-1))	69.9 deg F	74.2 deg F	89.5 deg F	86 % open	280 cfm	277 cfm	36 %
BT1.LEVEL 2.ATS-1-2-12 (Corridor 2200C1 (BT1-AHU-R-1))	71.7 deg F	72.0 deg F	62.0 deg F	0 % open	900 cfm	892 cfm	80 %
BT1.LEVEL 2.ATS-1-2-15 (Soiled Utility 22032 (BT1-AHU-R-1))	70.6 deg F	72.0 deg F	71.5 deg F	17 % open	300 cfm	300 cfm	70 %
BT1.LEVEL 2.ATS-1-2-13 (Nurses Station 21053 (BT1-AHU-R-1))	69.9 deg F	68.0 deg F	61.2 deg F	0 % open	250 cfm	252 cfm	40 %
BT1.LEVEL 2.ATS-1-2-14 (Clean Linen Utility 22030 (BT1-AHU-R-1))	69.9 deg F	72.0 deg F	75.8 deg F	26 % open	300 cfm	300 cfm	52 %
BT1.LEVEL 2.ATS-1-2-16 (Team Command Center 22026 (BT1-AHU-R-1))	70.0 deg F	68.0 deg F	63.4 deg F	0 % open	301 cfm	604 cfm	48 %
BT1.LEVEL 2.ATS-1-2-17 (Monitoring 21048 (BT1-AHU-R-1))	70.2 deg F	68.0 deg F	69.7 deg F	0 % open	106 cfm	104 cfm	29 %
BT1.LEVEL 2.ATS-1-2-18 (Meds Room 21058 & 21059 (BT1-AHU-R-1))	69.8 deg F	68.0 deg F	65.7 deg F	0 % open	400 cfm	399 cfm	55 %
BT1.LEVEL 2.ATS-1-2-20 (CN4 Office 22027 (BT1-AHU-R-1))	70.1 deg F	68.0 deg F	65.4 deg F	0 % open	100 cfm	100 cfm	33 %
BT1.LEVEL 2.ATS-1-2-21 (Nurses Station 22025 (BT1-AHU-R-1))	70.9 deg F	68.0 deg F	61.9 deg F	0 % open	366 cfm	366 cfm	44 %
BT1.LEVEL 2.ATS-1-2-22 (Corridor 2100C3 (BT1-AHU-R-1))	69.9 deg F	72.0 deg F	62.4 deg F	21 % open	950 cfm	950 cfm	74 %
BT1.LEVEL 2.ATS-1-2-23 (Team Work Education 21032 (BT1-AHU-R-1))	69.9 deg F	68.0 deg F	63.1 deg F	0 % open	135 cfm	132 cfm	43 %
BT1.LEVEL 2.ATS-1-2-24 (Staff Lounge 22012 (BT1-AHU-R-1))	70.3 deg F	71.8 deg F	76.4 deg F	23 % open	700 cfm	696 cfm	92 %
BT1.LEVEL 2.ATS-1-2-25 (Equipment Storage 2200C6 (BT1-AHU-R-1))	70.2 deg F	72.0 deg F	63.5 deg F	22 % open	300 cfm	299 cfm	44 %
BT1.LEVEL 2.ATS-1-2-28 (Patient Room 22015 (BT1-AHU-R-1))	70.6 deg F	68.0 deg F	62.4 deg F	0 % open	313 cfm	309 cfm	54 %
BT1.LEVEL 2.ATS-1-2-29 (Patient Room 22016 (BT1-AHU-R-1))	69.9 deg F	68.4 deg F	63.4 deg F	0 % open	280 cfm	281 cfm	61 %
BT1.LEVEL 2.ATS-1-2-30 (Patient Room 22017 (BT1-AHU-R-1))	69.9 deg F	68.0 deg F	64.1 deg F	0 % open	280 cfm	283 cfm	46 %
BT1.LEVEL 2.ATS-1-2-31 (Patient Room 22018 (BT1-AHU-R-1))	70.0 deg F	68.0 deg F	70.5 deg F	0 % open	280 cfm	277 cfm	27 %
BT1.LEVEL 2.ATS-1-2-32 (Patient Room 22019 (BT1-AHU-R-1))	69.9 deg F	68.0 deg F	69.7 deg F	0 % open	285 cfm	281 cfm	45 %
BT1.LEVEL 2.ATS-1-2-33 (Patient Room 22020 (BT1-AHU-R-1))	70.0 deg F	68.0 deg F	62.8 deg F	0 % open	280 cfm	278 cfm	49 %
BT1.LEVEL 2.ATS-1-2-34 (Patient Room 22021 (BT1-AHU-R-1))	70.2 deg F	68.0 deg F	74.2 deg F	0 % open	280 cfm	281 cfm	42 %

Terminal Unit functional Testing – via BAS

	Supply Air Terminal Unit								Return Air Terminal Unit												
	Setpoint Verification				Supply Damper Control				Setpoint Verification				EAV Damper Control				DAT/ HW Valve Operation				
Supply Terminal Unit	Maximum Flow Setpoint (cfm)	Minimum Flow Setpoint (cfm)	Heating Flow Setpoint (cfm)	All Flow Setpoints Correct?	BAS Reading Maximum (cfm)	Damper Position	BAS Reading Heating (cfm)	Damper Position	Maximum Flow Setpoint (cfm)	Minimum Flow Setpoint (cfm)	Heating Flow Setpoint (cfm)	All Flow Setpoints Correct?	BAS Reading Maximum (cfm)	Damper Position	BAS Reading Heating (cfm)	Damper Position	AHU DAT (°F)	DAT w/Valve Closed (°F)	DAT w/Valve Open (°F)	Coil Output (MBH)	Scheduled Output
BT1.LEVEL 2.ATS-1-2-1 (Nurse Manager Office 22010 (BT1-AH	200 cfm	100 cfm	100 cfm	✓	201 cfm	40 %	98 cfm	30 %	198 cfm	106 cfm	98 cfm	✓	204 cfm	54 %	92 cfm	37 %	65.0 °F	66.1 °F	116.9 °F	5.5 MBH	4.2 MBH
BT1.LEVEL 2.ATS-1-2-2 (Phys Workroom 22009 (BT1-AHU-R-1))	600 cfm	300 cfm	300 cfm	✓	551 cfm	100 %	295 cfm	38 %	552 cfm	295 cfm	295 cfm	✓	558 cfm	75 %	299 cfm	38 %	65.0 °F	66.0 °F	110.3 °F	14.4 MBH	10.6 MBH
BT1.LEVEL 2.ATS-1-2-3 (Patient Room 22008 (BT1-AHU-R-1))	500 cfm	280 cfm	280 cfm	✓	504 cfm	77 %	280 cfm	43 %	303 cfm	80 cfm	80 cfm	✓	301 cfm	84 %	87 cfm	39 %	65.0 °F	63.2 °F	105.6 °F	12.3 MBH	10.1 MBH
BT1.LEVEL 2.ATS-1-2-4 (Patient Room 22007 (BT1-AHU-R-1))	500 cfm	280 cfm	280 cfm	✓	502 cfm	66 %	290 cfm	41 %	303 cfm	90 cfm	90 cfm	✓	304 cfm	77 %	87 cfm	33 %	65.0 °F	66.1 °F	99.8 °F	10.9 MBH	10.1 MBH
BT1.LEVEL 2.ATS-1-2-5 (Patient Room 22006 (BT1-AHU-R-1))	500 cfm	280 cfm	280 cfm	✓	508 cfm	66 %	275 cfm	38 %	306 cfm	75 cfm	75 cfm	✓	303 cfm	91 %	81 cfm	37 %	66.3 °F	65.7 °F	66.5 °F	0.1 MBH	10.1 MBH
BT1.LEVEL 2.ATS-1-2-6 (Patient Room 22005 (BT1-AHU-R-1))	500 cfm	280 cfm	280 cfm	✓	505 cfm	73 %	290 cfm	43 %	301 cfm	90 cfm	90 cfm	✓	258 cfm	100 %	87 cfm	38 %	65.0 °F	64.1 °F	107.7 °F	13.4 MBH	10.1 MBH
BT1.LEVEL 2.ATS-1-2-7 (Patient Room 22004 (BT1-AHU-R-1))	500 cfm	280 cfm	280 cfm	✓	512 cfm	68 %	290 cfm	43 %	313 cfm	90 cfm	90 cfm	✓	266 cfm	100 %	88 cfm	36 %	65.0 °F	65.6 °F	103.1 °F	11.9 MBH	10.1 MBH
BT1.LEVEL 2.ATS-1-2-8 (Patient Room 22003 (BT1-AHU-R-1))	500 cfm	280 cfm	280 cfm	✓	506 cfm	68 %	283 cfm	41 %	301 cfm	83 cfm	83 cfm	✓	269 cfm	100 %	76 cfm	42 %	65.0 °F	65.8 °F	107.3 °F	12.9 MBH	10.1 MBH
BT1.LEVEL 2.ATS-1-2-9 (Patient Room 22002 (BT1-AHU-R-1))	500 cfm	280 cfm	280 cfm	✓	506 cfm	100 %	280 cfm	43 %	305 cfm	80 cfm	76 cfm	✓	278 cfm	100 %	76 cfm	38 %	65.0 °F	65.6 °F	105.6 °F	12.3 MBH	10.1 MBH
BT1.LEVEL 2.ATS-1-2-10 (Patient Room 22001 (BT1-AHU-R-1))	500 cfm	280 cfm	280 cfm	✓	462 cfm	100 %	284 cfm	47 %	261 cfm	84 cfm	84 cfm	✓	216 cfm	100 %	91 cfm	43 %	65.0 °F	65.9 °F	99.2 °F	10.5 MBH	10.1 MBH
BT1.LEVEL 2.ATS-1-2-11 (Patient Room 21008 (BT1-AHU-R-1))	500 cfm	280 cfm	280 cfm	✓	507 cfm	79 %	274 cfm	39 %	304 cfm	74 cfm	74 cfm	✓	211 cfm	100 %	76 cfm	42 %	65.0 °F	65.8 °F	99.0 °F	10.1 MBH	10.1 MBH
BT1.LEVEL 2.ATS-1-2-12 (Corridor 2200C1 (BT1-AHU-R-1))	900 cfm	900 cfm	900 cfm	✓	900 cfm	100 %	893 cfm	46 %	965 cfm	943 cfm	943 cfm	✗	919 cfm	100 %	943 cfm	67 %	65.0 °F	65.6 °F	90.8 °F	24.9 MBH	21.9 MBH
BT1.LEVEL 2.ATS-1-2-15 (Soiled Utility 22032 (BT1-AHU-R-1))	300 cfm	300 cfm	300 cfm	✓	304 cfm	46 %	291 cfm	43 %	955 cfm	941 cfm	941 cfm	✗	955 cfm	81 %	957 cfm	67 %	65.0 °F	65.9 °F	99.7 °F	10.9 MBH	6.5 MBH
BT1.LEVEL 2.ATS-1-2-13 (Nurses Station 21053 (BT1-AHU-R-1)	500 cfm	250 cfm	250 cfm	✓	499 cfm	61 %	248 cfm	39 %	409 cfm	148 cfm	148 cfm	✓	411 cfm	55 %	141 cfm	39 %	65.0 °F	64.3 °F	99.5 °F	9.2 MBH	5.4 MBH
BT1.LEVEL 2.ATS-1-2-14 (Clean Linen Utility 22030 (BT1-AHU-	600 cfm	300 cfm	300 cfm	✓	590 cfm	63 %	295 cfm	40 %	390 cfm	92 cfm	93 cfm	✓	392 cfm	53 %	99 cfm	31 %	65.0 °F	65.5 °F	100.7 °F	11.4 MBH	6.5 MBH
BT1.LEVEL 2.ATS-1-2-16 (Team Command Center 22026 (BT1-/	600 cfm	300 cfm	300 cfm	✓	606 cfm	61 %	295 cfm	38 %	601 cfm	295 cfm	295 cfm	✓	604 cfm	63 %	298 cfm	42 %	65.0 °F	65.1 °F	88.5 °F	7.5 MBH	6.5 MBH
BT1.LEVEL 2.ATS-1-2-18 (Meds Room 21058 & 21059 (BT1-AH	400 cfm	400 cfm	400 cfm	✓	409 cfm	57 %	408 cfm	52 %	204 cfm	208 cfm	208 cfm	✓	207 cfm	54 %	210 cfm	51 %	65.0 °F	63.5 °F	94.4 °F	13.0 MBH	8.7 MBH
BT1.LEVEL 2.ATS-1-2-17 (Monitoring 21048 (BT1-AHU-R-1))	200 cfm	100 cfm	100 cfm	✓	200 cfm	48 %	108 cfm	35 %	200 cfm	108 cfm	108 cfm	✓	201 cfm	45 %	108 cfm	32 %	65.0 °F	65.7 °F	99.0 °F	4.0 MBH	2.2 MBH
BT1.LEVEL 2.ATS-1-2-21 (Nurses Station 22025 (BT1-AHU-R-1)	600 cfm	300 cfm	300 cfm	✓	605 cfm	66 %	308 cfm	41 %	702 cfm	408 cfm	408 cfm	✓	719 cfm	83 %	391 cfm	52 %	65.0 °F	65.1 °F	89.4 °F	8.1 MBH	6.5 MBH
BT1.LEVEL 2.ATS-1-2-20 (CN4 Office 22027 (BT1-AHU-R-1))	100 cfm	100 cfm	100 cfm	✓	100 cfm	38 %	104 cfm	35 %	100 cfm	104 cfm	104 cfm	✓	4 cfm	100 %	4 cfm	100 %	65.0 °F	66.1 °F	93.7 °F	3.2 MBH	2.2 MBH
BT1.LEVEL 2.ATS-1-2-23 (Team Work Education 21032 (BT1-AH	260 cfm	130 cfm	130 cfm	✓	262 cfm	55 %	133 cfm	30 %	261 cfm	133 cfm	133 cfm	✓	263 cfm	73 %	145 cfm	44 %	65.0 °F	66.0 °F	94.5 °F	4.2 MBH	2.8 MBH
BT1.LEVEL 2.ATS-1-2-22 (Corridor 2100C3 (BT1-AHU-R-1))	950 cfm	950 cfm	950 cfm	✓	959 cfm	89 %	948 cfm	77 %	789 cfm	778 cfm	778 cfm	✓	788 cfm	62 %	765 cfm	55 %	65.0 °F	65.5 °F	86.7 °F	22.2 MBH	23.0 MBH
BT1.LEVEL 2.ATS-1-2-25 (Equipment Storage 2200C6 (BT1-AHU	600 cfm	300 cfm	300 cfm	✓	602 cfm	64 %	296 cfm	39 %	602 cfm	296 cfm	296 cfm	✓	600 cfm	89 %	293 cfm	65 %	65.0 °F	65.5 °F	91.4 °F	8.4 MBH	6.5 MBH
BT1.LEVEL 2.ATS-1-2-24 (Staff Lounge 22012 (BT1-AHU-R-1))	700 cfm	700 cfm	700 cfm	✓	682 cfm	100 %	694 cfm	80 %									65.0 °F	65.9 °F	93.6 °F	21.5 MBH	19.7 MBH
BT1.LEVEL 2.ATS-1-2-29 (Patient Room 22016 (BT1-AHU-R-1))	500 cfm	280 cfm	280 cfm	✓	504 cfm	68 %	292 cfm	41 %	302 cfm	92 cfm	92 cfm	✓	298 cfm	100 %	84 cfm	35 %	65.0 °F	65.4 °F	107.8 °F	13.5 MBH	10.1 MBH

Terminal Unit functional Testing
Damper Operation

	Return Air Terminal Unit							
	Setpoint Verification				EAV Damper Control			
Supply Terminal Unit	Maximum Flow Setpoint (cfm)	Minimum Flow Setpoint (cfm)	Heating Flow Setpoint (cfm)	All Flow Setpoints Correct?	BAS Reading Maximum (cfm)	Damper Position	BAS Reading Heating (cfm)	Damper Position
BT1.LEVEL 3.ATS-1-3-6 (Patient Room 32005 (BT1-AHU-R-1))	357 cfm	179 cfm	182 cfm	✓	352 cfm	55 %	181 cfm	41 %
BT1.LEVEL 3.ATS-1-3-7 (Patient Room 32004 (BT1-AHU-R-1))	356 cfm	191 cfm	177 cfm	✓	352 cfm	47 %	178 cfm	28 %
BT1.LEVEL 3.ATS-1-3-8 (Patient Room 32003 (BT1-AHU-R-1))	361 cfm	172 cfm	197 cfm	✓	362 cfm	49 %	193 cfm	37 %
BT1.LEVEL 3.ATS-1-3-9 (Patient Room 32002 (BT1-AHU-R-1))	361 cfm	179 cfm	177 cfm	✓	367 cfm	50 %	179 cfm	32 %
BT1.LEVEL 3.ATS-1-3-10 (Patient Room 32001 (BT1-AHU-R-1))	357 cfm	182 cfm	178 cfm	✓	355 cfm	58 %	190 cfm	40 %
BT1.LEVEL 3.ATS-1-3-11 (Corridor 320C3 (BT1-AHU-R-1))	828 cfm	823 cfm	854 cfm	✓	0 cfm	100 %	0 cfm	100 %
BT1.LEVEL 3.ATS-1-3-12 (MD Work Room 32039 (BT1-AHU-R-1))	399 cfm	198 cfm	199 cfm	✓	401 cfm	66 %	198 cfm	37 %
BT1.LEVEL 3.ATS-1-3-13 (Treatment 32037 (BT1-AHU-R-1))	201 cfm	199 cfm	199 cfm	✓	197 cfm	47 %	201 cfm	44 %
BT1.LEVEL 3.ATS-1-3-14 (Nourishment 32038 (BT1-AHU-R-1))								
BT1.LEVEL 3.ATS-1-3-15 (Soiled 32033 (BT1-AHU-R-1))								
BT1.LEVEL 3.ATS-1-3-16 (Med Storage 32034 (BT1-AHU-R-1))	99 cfm	99 cfm	99 cfm	✓	100 cfm	97 %	101 cfm	62 %
BT1.LEVEL 3.ATS-1-3-17 (Nurse Work 32032 (BT1-AHU-R-1))	696 cfm	343 cfm	347 cfm	✓	702 cfm	58 %	354 cfm	37 %
BT1.LEVEL 3.ATS-1-3-18 (Office 32030 (BT1-AHU-R-1))	100 cfm	99 cfm	100 cfm	✓	99 cfm	18 %	100 cfm	16 %
BT1.LEVEL 3.ATS-1-3-21 (Nourishment 32027 (BT1-AHU-R-1))								
BT1.LEVEL 3.ATS-1-3-20 (Clean Utility 32030 (BT1-AHU-R-1))	498 cfm	98 cfm	96 cfm	✓	499 cfm	65 %	110 cfm	32 %
BT1.LEVEL 3.ATS-1-3-23 (Office 32036 (BT1-AHU-R-1))	99 cfm	100 cfm	101 cfm	✓	98 cfm	40 %	100 cfm	36 %
BT1.LEVEL 3.ATS-1-3-22 (Equipment Storage 32025 (BT1-AHU-R-1))	300 cfm	151 cfm	149 cfm	✓	298 cfm	62 %	149 cfm	46 %
BT1.LEVEL 3.ATS-1-3-25 (Equipment Storage 32023 (BT1-AHU-R-1))	611 cfm	299 cfm	299 cfm	✓	598 cfm	66 %	300 cfm	55 %

Terminal Unit functional Testing
Reheat Valve Operation

Supply Terminal Unit	DAT/ HW Valve Operation				
	AHU DAT (°F)	DAT w/Valve Closed (°F)	DAT w/Valve Open (°F)	Coil Output (MBH)	Scheduled Output
BT1.LEVEL 1.ATS-1-1-06 (Corridor 100C4 (BT1-AHU-R-1))	61.0 °F	62.1 °F	90.0 °F	28.3 MBH	19.5 MBH
BT1.LEVEL 1.ATS-1-1-11 (Clerical Work 11004 (BT1-AHU-R-1))	61.0 °F	62.7 °F	87.3 °F	2.8 MBH	2.2 MBH
BT1.LEVEL 1.ATS-1-1-12 (Safety Officer Conf Storage 11003/11005 (BT1-AHU-R-1))	61.0 °F	62.6 °F	86.0 °F	4.3 MBH	3.5 MBH
BT1.LEVEL 1.ATS-1-1-13 (Conference 10012 (BT1-AHU-R-1))	61.0 °F	65.4 °F	141.8 °F	6.4 MBH	1.6 MBH
BT1.LEVEL 1.ATS-1-1-14 (Shared Training 10011 (BT1-AHU-R-1))	61.0 °F	61.6 °F	85.3 °F	6.8 MBH	5.8 MBH
BT1.LEVEL 1.ATS-1-1-15 (Female Staff Lockers Toilet 10009/10010 (BT1-AHU-R-1))	61.0 °F	62.1 °F	90.7 °F	11.1 MBH	7.6 MBH
BT1.LEVEL 1.ATS-1-1-16 (Male Staff Lockers Toilet 10008/10007 (BT1-AHU-R-1))	61.0 °F	61.7 °F	85.0 °F	8.3 MBH	6.9 MBH
BT1.LEVEL 1.ATS-1-1-17 (Corridor 1100C1 (BT1-AHU-R-1))	61.0 °F	62.5 °F	84.1 °F	14.9 MBH	13.0 MBH
BT1.LEVEL 1.ATS-1-1-18 (Shared Training 10011 (BT1-AHU-R-1))	61.0 °F	62.1 °F	92.7 °F	4.6 MBH	2.9 MBH
BT1.LEVEL 1.ATS-1-1-20 (Library 10001A (BT1-AHU-R-1))	61.0 °F	62.6 °F	80.7 °F	9.5 MBH	16.4 MBH
BT1.LEVEL 1.ATS-1-1-21 (Physician Lounge 10001 (BT1-AHU-R-1))	61.0 °F	62.2 °F	91.0 °F	14.5 MBH	13.5 MBH
BT1.LEVEL 1.ATS-1-1-22 (Physicians Lockers 10000 (BT1-AHU-R-1))	61.0 °F	62.7 °F	96.1 °F	12.1 MBH	13.1 MBH
BT1.LEVEL 1.ATS-1-1-23 (Office's 10004/10005 (BT1-AHU-R-1))	61.0 °F	62.4 °F	89.3 °F	6.1 MBH	4.3 MBH
BT1.LEVEL 1.ATS-1-1-24-1 (Staff Lounge 10003 (BT1-AHU-R-1))	61.0 °F	62.2 °F	80.2 °F	20.4 MBH	36.3 MBH
BT1.LEVEL 1.ATS-1-1-24-2 (Staff Lounge 10003 (BT1-AHU-R-1))	61.0 °F	61.5 °F	79.5 °F	19.9 MBH	21.7 MBH
BT1.LEVEL 1.ATS-1-1-25 (Fitness Office 10006A (BT1-AHU-R-1))	61.0 °F	62.5 °F	63.4 °F	0.2 MBH	1.5 MBH
BT1.LEVEL 1.ATS-1-1-26 (Employee Recreation Fitness 10006 (BT1-AHU-R-1))	61.0 °F	61.9 °F	94.0 °F	24.2 MBH	25.6 MBH

Conclusion: Terminal Unit Testing

- Contractors are not always diligent about repetitive testing and checking of numerous terminal units.
- A cost effective solution is to utilize the tools at hand to maximize testing and verification.
- Prevents potentially skipping over "bad" units or devices on a particular unit when utilizing a traditional sampling method.

COMMISSIONING FINDS AND SOLUTIONS

AN OWNER'S PROSPECTIVE ON COMMISSIONING

ROD RABOLD, Commissioning Coordinator/ Engineer, UNC-Chapel Hill

North Carolina State Construction Conference : March 26, 2015

BUILDING COMMISSIONING COSTS
TO CX SB 668 REQUIRED SYSTEMS

Type of Building	Cx Cost as a % of Construction Budget
Simple Academic or Residence Buildings served by campus utilities (CHW and HW)	1% or less
Mixed Use Buildings, Academic Building on own utilities	1.5%
Research Building	2%
Complex Research or Specialty Building	3% or more

When it comes to Cx costs size does matter, the smaller projects can be more costly to commission as a % of the total construction budget.

DESIGN REVIEW ISSUES – FOUND

HVAC LAB CONTROLLERS TO BE LOCATED 12 FT OFF FLOOR

DESIGN REVIEW ISSUES – MISSED WATER & DRAIN LINES ABOVE A SERVER RM

FUNCTIONAL TESTING OF SERVER RM

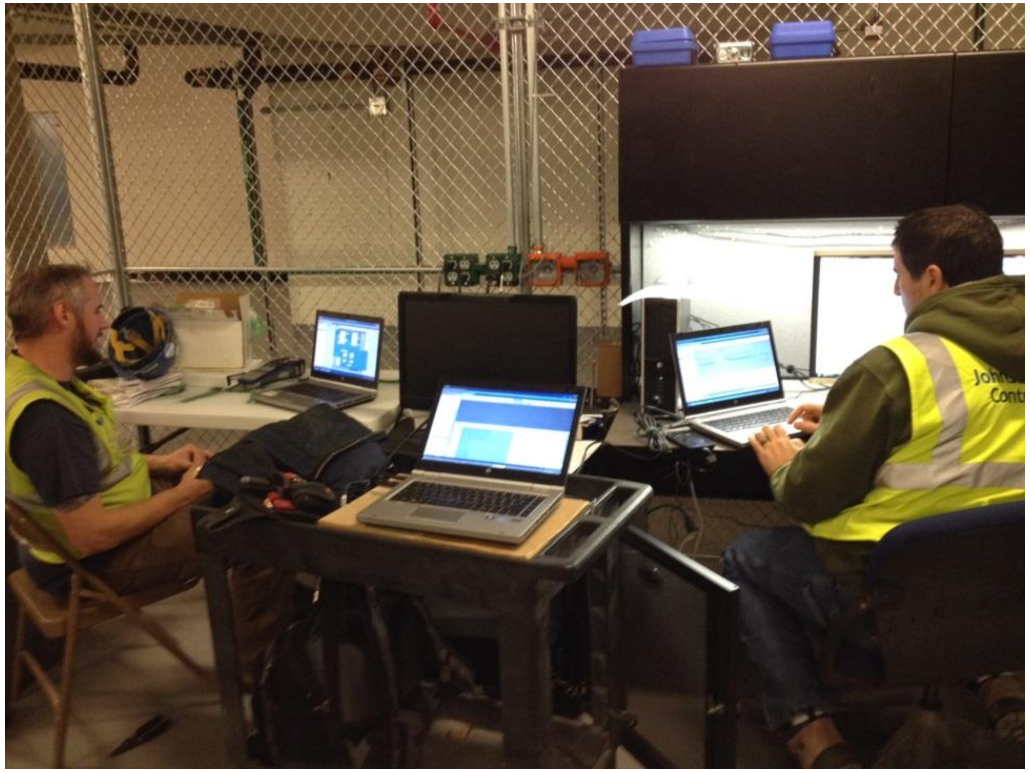
Resistive Load Bank

100 KW UPS under test

CX IS A "LEARNING" EXPERIENCE

- Early startup of AHUs to conditioned the building without the controls being fully operational and commissioned resulted in numerous duct failures in this one project.

MY 3 TOP AREAS OF CX FOCUS - CONTROLS, CONTROLS, CONTROLS



WHY CONTROLS

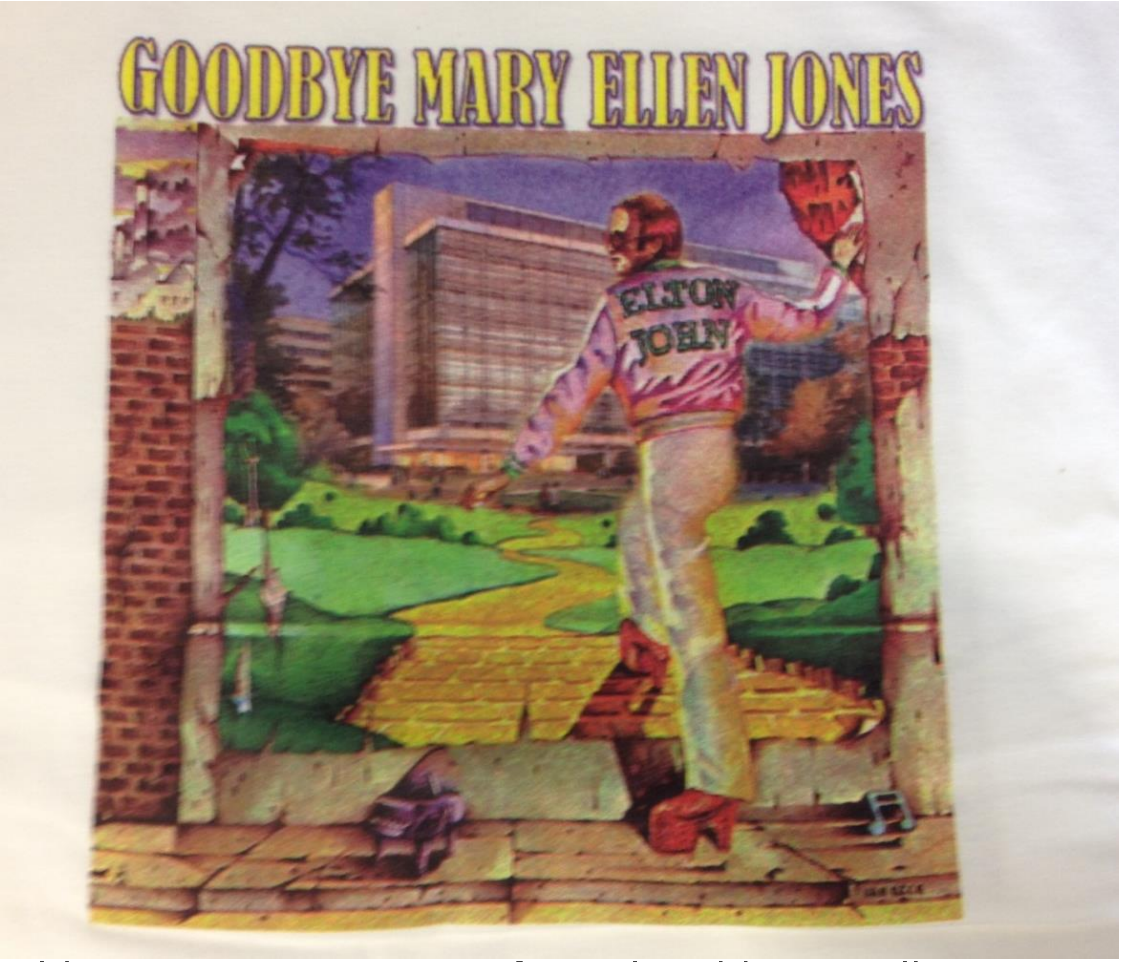
- Low Bid Selection Process
- Complexity given the demands of building and energy codes and advanced technology
- Time constraints in that the controls are having to be completed in a compressed schedule or post occupancy.
- Poorly thought out or defined control sequence of operations.

OWNER NEEDS TO EMPHASIS THE CX PROCESS AND 'PARTICIPATE' IN CX MEETINGS

BUILDING ACCEPTANCE

There can be a big difference between a building being ready for SCO Beneficial Occupancy inspection versus completing the final commissioning of non-life safety systems (such as HVAC systems and controls).

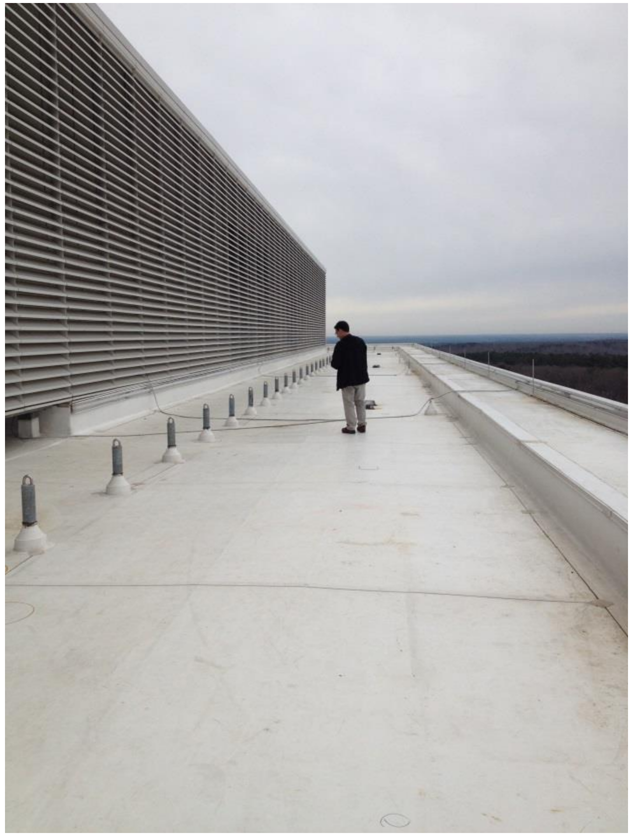
WHEN THE BUILDING APPEARS READY THE OCCUPANTS ARE READY TO MOVE - NOW



Tee shirt given to new building occupants moving from the old Mary Ellen Jones

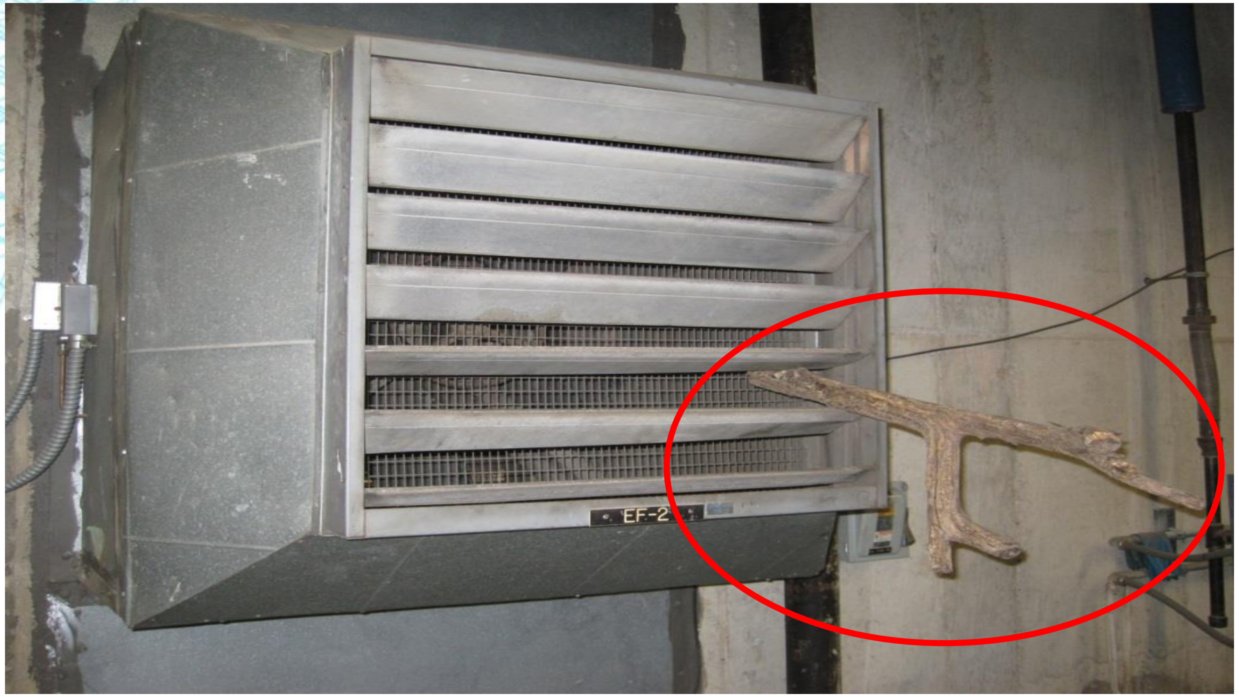
WARRANTY INSPECTIONS

Roof membrane was Cx during the Construction Phase



Membrane damage found during Cx Warranty Inspection

HOPEFULLY CX PREVENTS FUTURE PALEO BAS OPERATIONS – “STICKS AND BRICKS”



‘Maintenance staff will do “something” to fix an uncorrected building problem.’

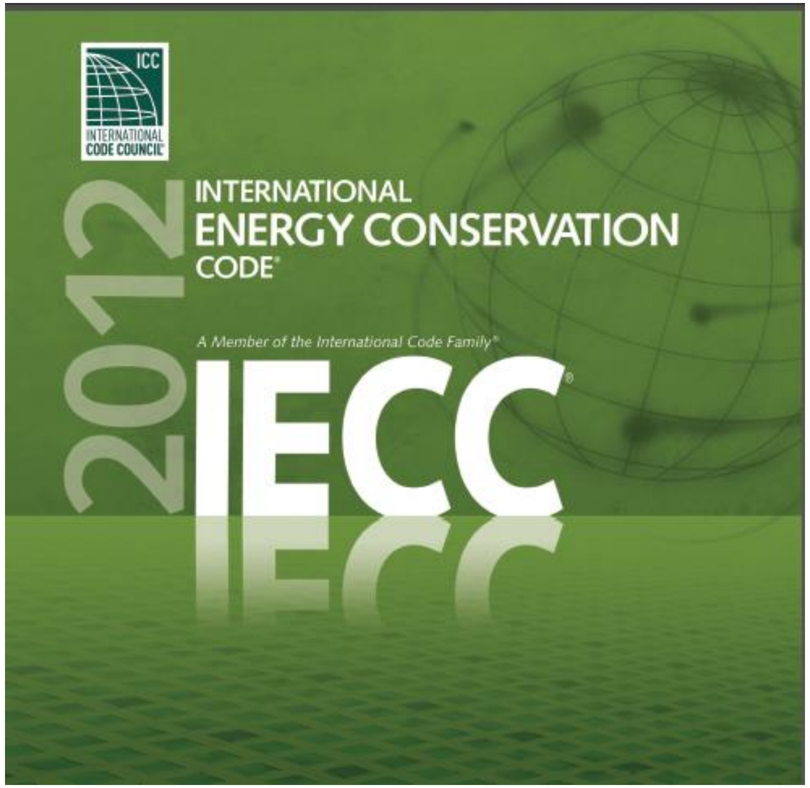
THE FUTURE OF BUILDING COMMISSIONING

There is a strong movement to add commissioning requirements to the building codes.

Code required building commissioning is coming - for better or for worse.

IEC 2012 – ENERGY CONSERVATION CODE REQUIRES COMMISSIONING

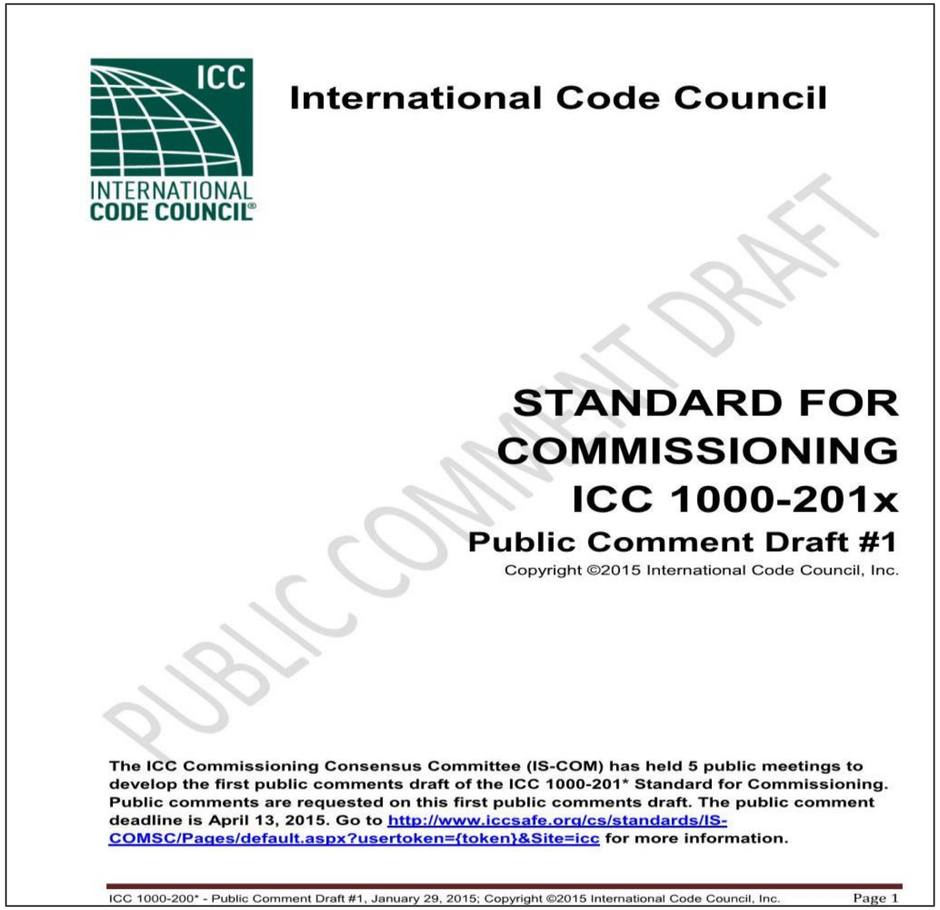
- Cx Plan
- Cx Functional Testing – HVAC Systems and Lighting
- Preliminary Cx Report Prior to Beneficial Occupancy
- Seasonal Testing and Warranty Review
- Final Cx Report



Delayed in NC until Jan 2019 by HB 120

ICC 1000-201* - STANDARD FOR COMMISSIONING

- First Public Draft – Comment period closes April 13th
- Deals with: Administration, Provider / Specialist Requirements (certification), and the Commissioning Process for <u>code compliance</u>
- Includes four (4) Appendices (A-D) – addressing <u>code compliance</u> forms



ICC INTERNATIONAL CODE COUNCIL

International Code Council

PUBLIC COMMENT DRAFT

STANDARD FOR COMMISSIONING

ICC 1000-201x

Public Comment Draft #1

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The ICC Commissioning Consensus Committee (IS-COM) has held 5 public meetings to develop the first public comments draft of the ICC 1000-201* Standard for Commissioning. Public comments are requested on this first public comments draft. The public comment deadline is April 13, 2015. Go to http://www.iccsafe.org/cs/standards/IS-COMSC/Pages/default.aspx?usertoken={token}&Site=icc for more information.

ICC 1000-200* - Public Comment Draft #1, January 29, 2015; Copyright ©2015 International Code Council, Inc. Page 1

ICC 1000 REQUIRES CXA CERTIFICATIONS, AS IN IAS AC476

12 AREAS OF COMMISSIONING SPECIALTIES

A. HVAC Systems

B. Lighting Systems

C. Plumbing Systems

D. Energy Systems

E. Irrigation Systems

F. Indoor Environmental Quality

G. Building Enclosure (Architectural Building Design)

H. Fire Protection Systems

I. Fire Alarm Systems

J. Vertical Conveyance Systems

K. Site Development and Land Use

L. Construction and Demolition Waste Management

FREE WEBINAR ON THE PROPOSED ICC 1000 REQUIREMENTS

The South Eastern Region of the Building Commissioning Association (SERBCA) is offering a free webinar on April 2, 2015 12:30 to 1:00 pm.

Flyers in the back or;

Email your Name and Company to Jim Magee:

jim@facomgrp.com

PANEL DISCUSSION

Panel members will provide answers to the following question;

'What the ______________ (Fill in the blank with project team member*, e.g. designer, contractor, owner*) can do to help the commissioning process deliver a better and more complete commissioned project?'