Control Verification

Gaylon Richardson, TBE
Engineered Air Balance Co., Inc.

This session will cover:

Complete verification testing of control systems is a key aspect of a fully commissioned building. This informative session will explain the requirements in the AABC/ANSI Total System Balance Standard, as well as how test and balance and commissioning firms can join forces and use their combined expertise to carry out the needed testing, verification and documentation.

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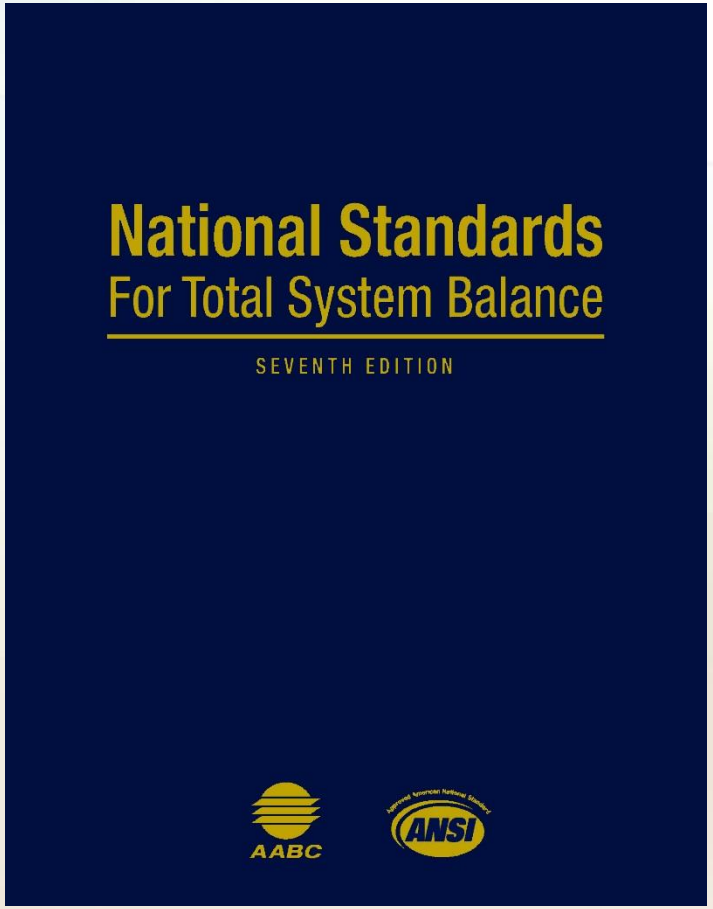
Learning Objectives

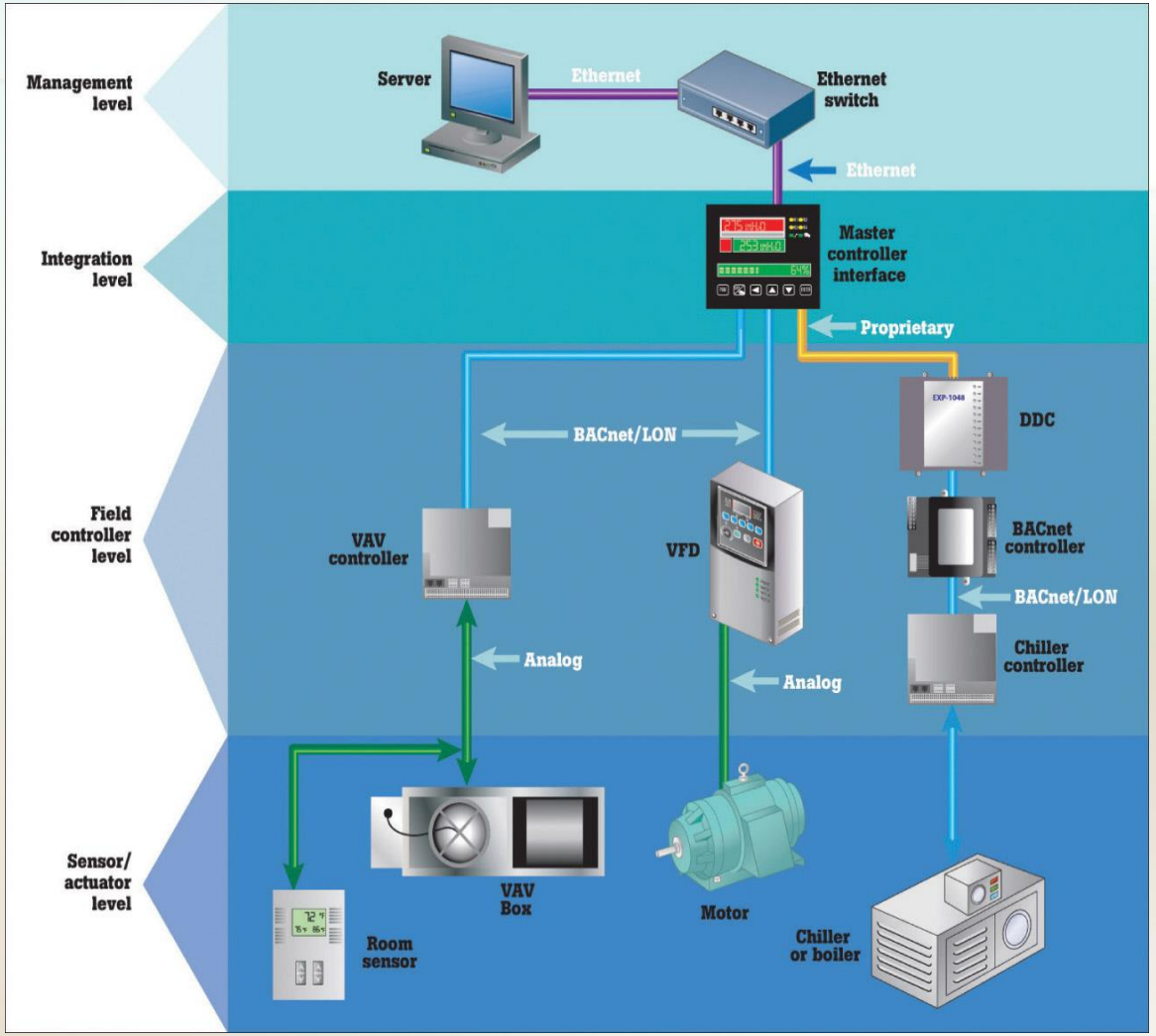
Objectives

- Understand the requirements for testing control components and systems in the ANSI/AABC National Standards For Total System Balancing.
- Understand when the verification must be documented and how.



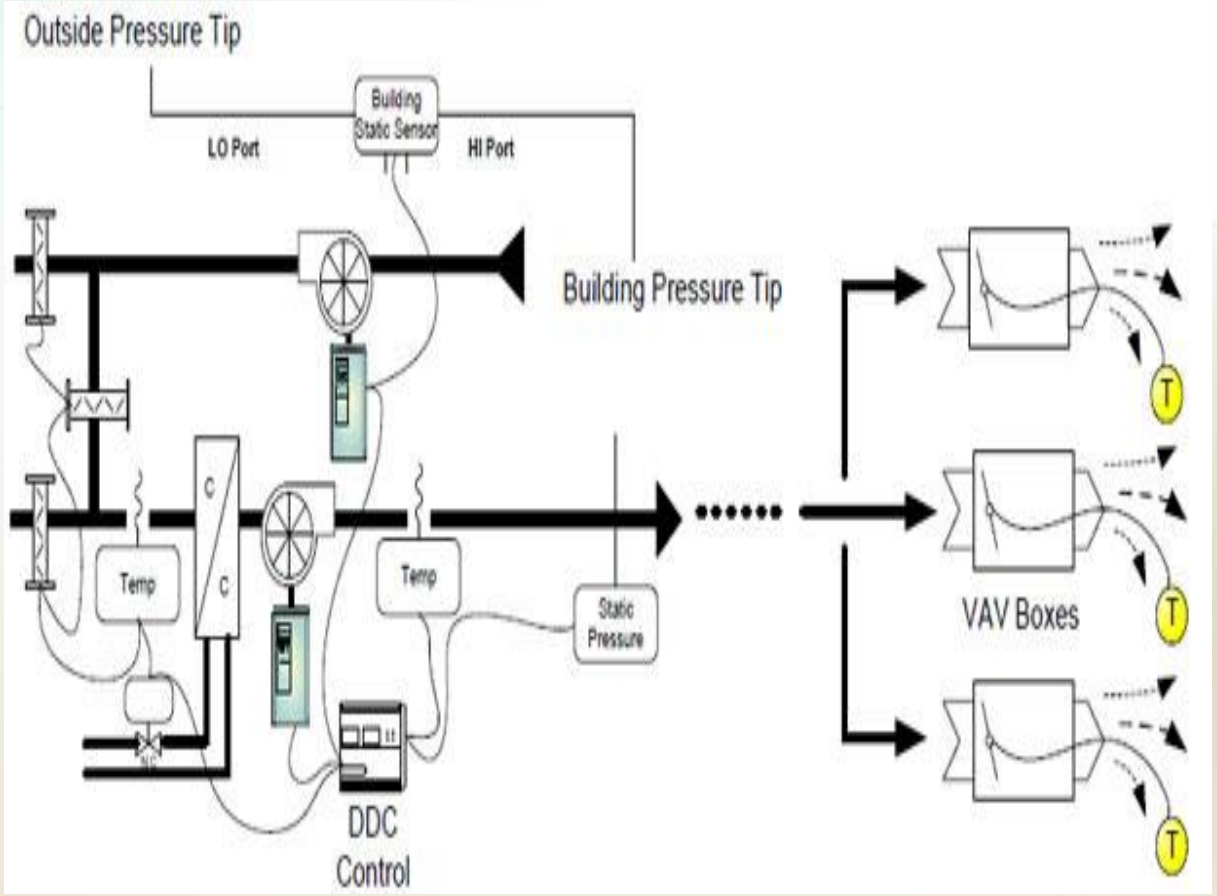
The AABC/ANSI National Standards for Total System Balance

- Identifies the responsibility of the TAB agency as verifying the control system operation meets the specification, and to report any functional or installations problems observed.



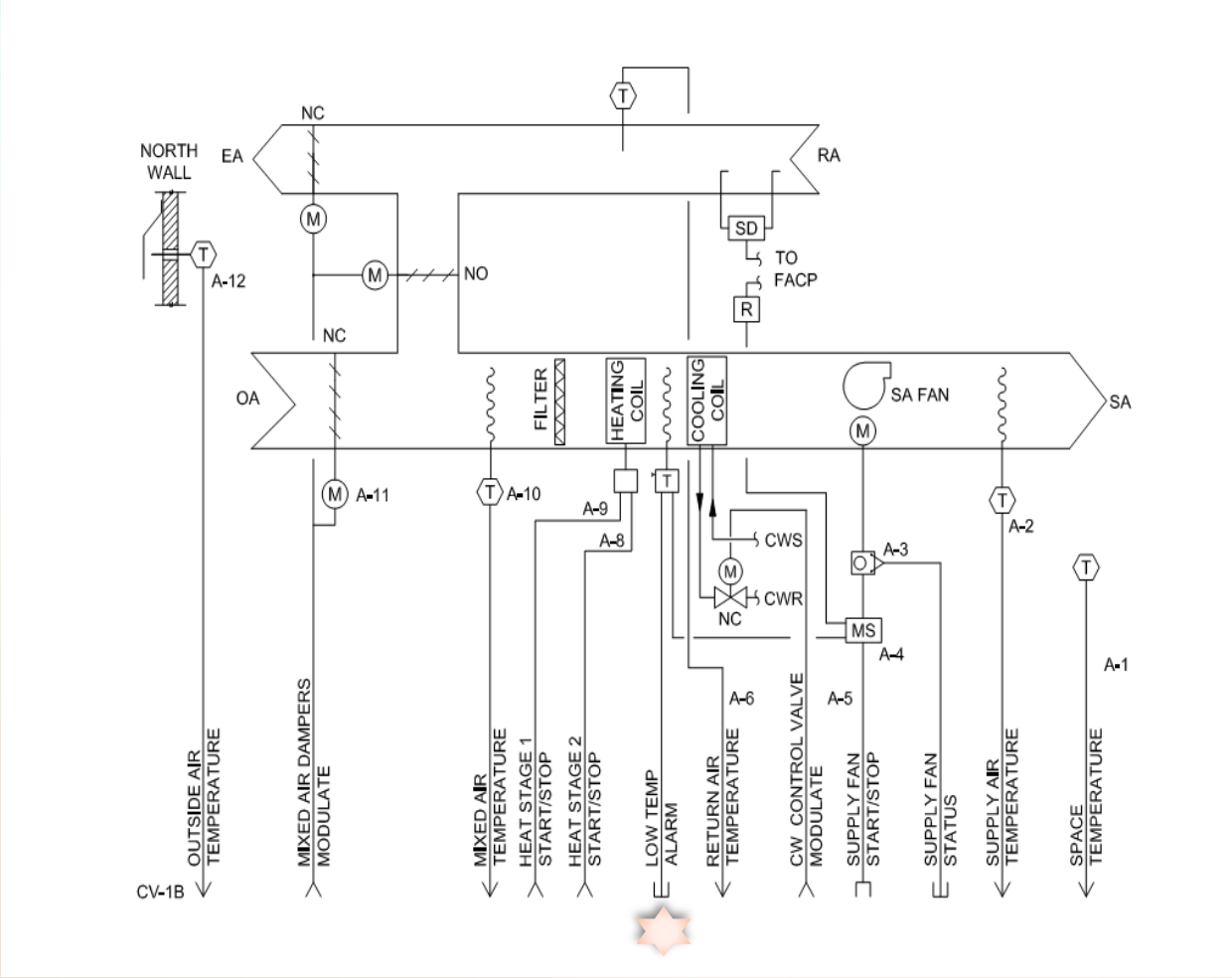
TAB Responsibilities When Not Specified

- Work with the temperature control contractor to ensure the system is operating within the design limitations, and obtain mutual understanding of intended control performance.



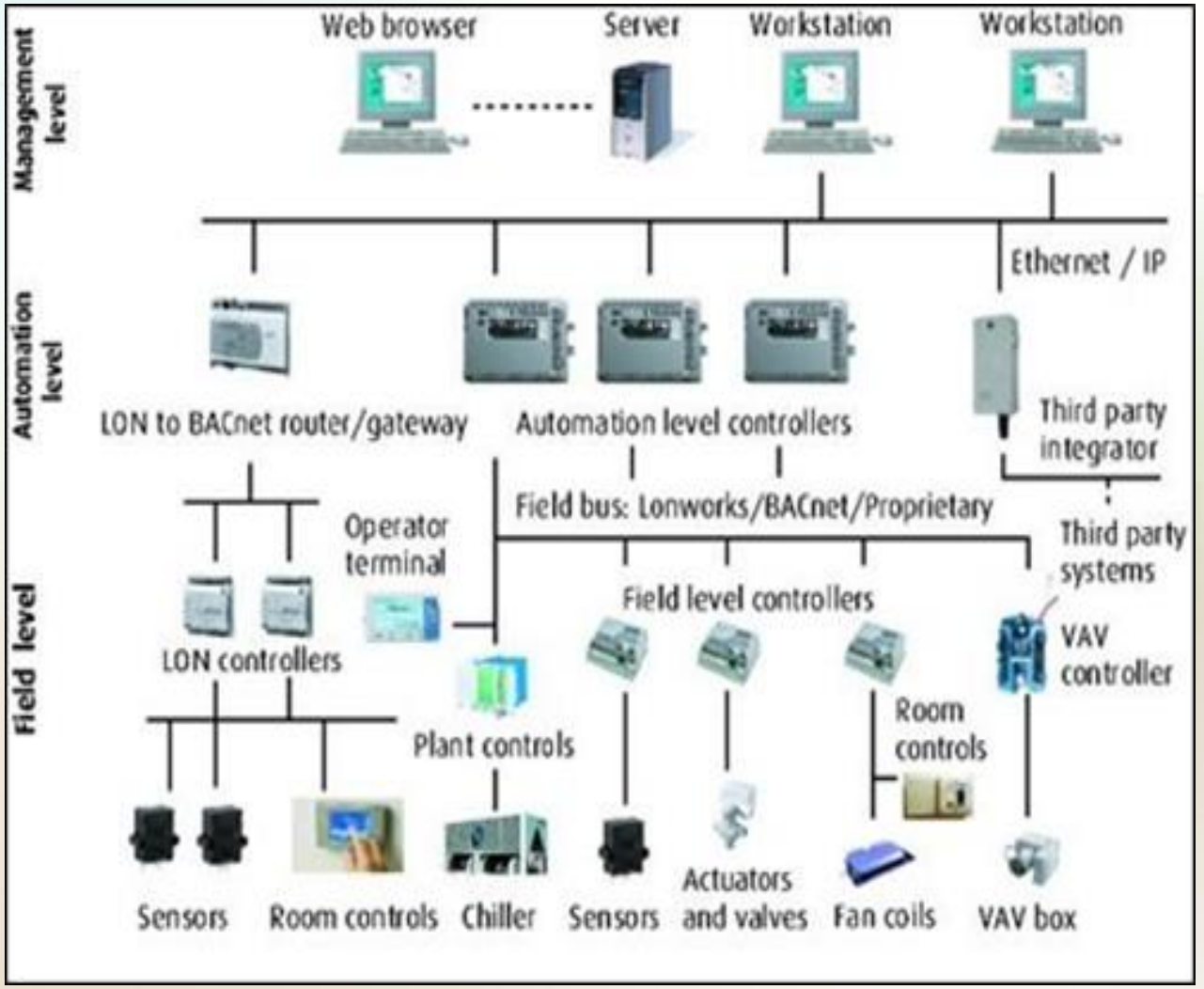
TAB Responsibilities When Not Specified

- Verify all hard-wired safety-limiting controllers such as freezestats and high/low static pressure shutdown controllers are calibrated, set at the required setpoint, and functional.



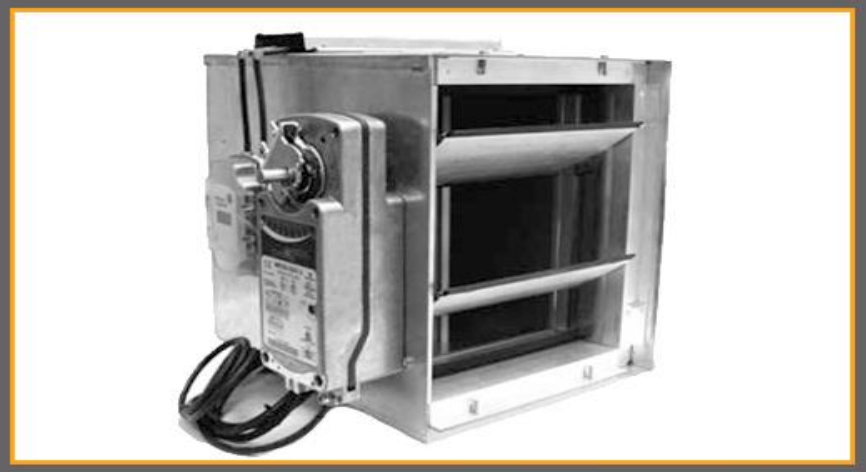
TAB Responsibilities When Not Specified

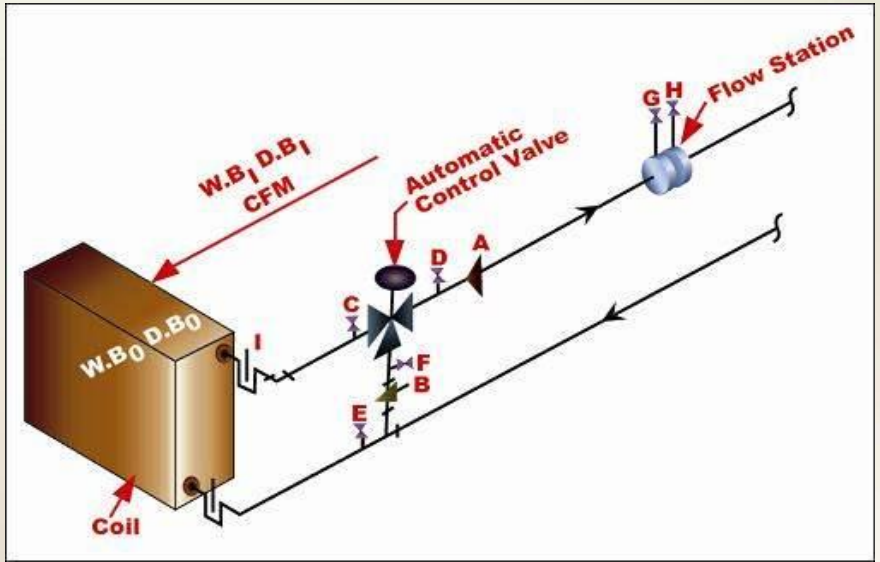
- Determine that all controlled devices are properly connected.
- Confirm that all controlled devices are operated by the intended controller.



TAB Responsibilities When Not Specified

- Verify that all flow monitoring stations for air and water are properly calibrated and reading correctly.



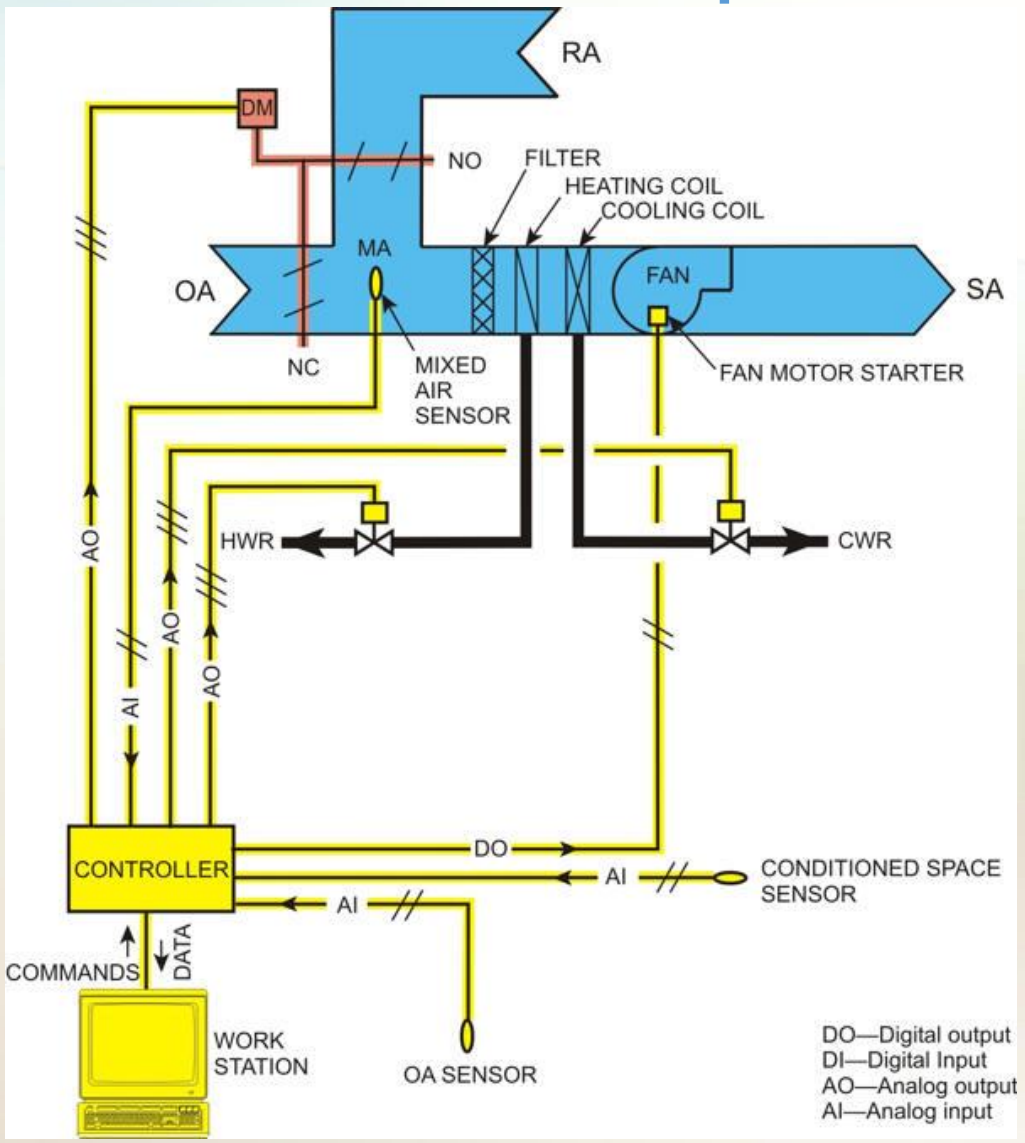


TAB Responsibilities When Not Specified

- Verify all temperature, humidity, and pressure sensors are properly calibrated and reading correctly

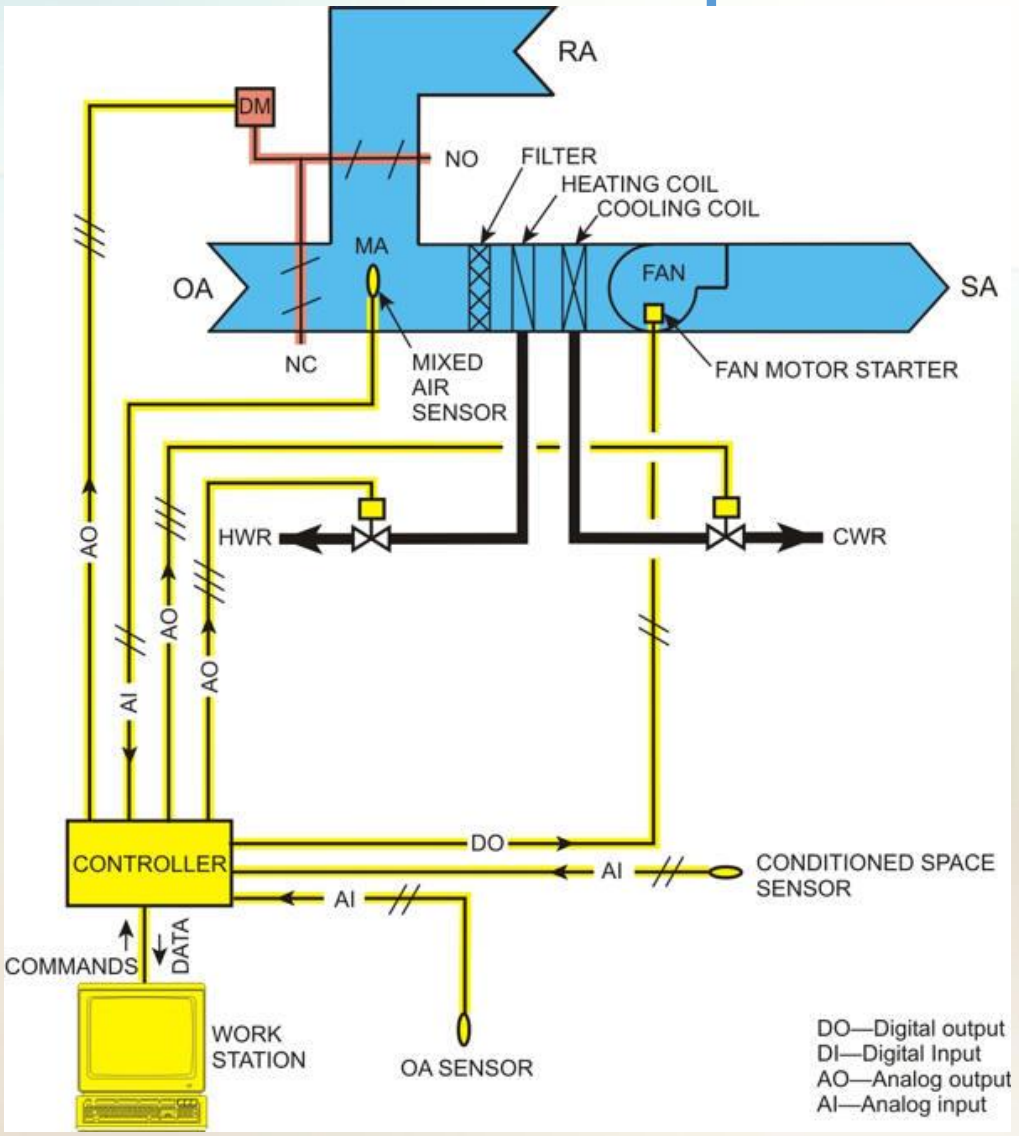
TAB Responsibilities When Not Specified

- Verify that controller setpoints meet the specification.
- Check the location and installation of all sensors to determine if they will sense only the intended temperature, humidity, or pressure. Also check for potential erratic operation due to outside influences such as sunlight, drafts, outside walls, etc.



TAB Responsibilities When Not Specified

- Check the operation of all control valve and damper actuators. Verify the valve or damper opens and closes 100%.
- Verify simultaneous heating and cooling does not occur.
- Confirm that all controlled devices are in the position indicated by the controller: open, closed, or modulating. Note any controlled devices that do not have free travel.



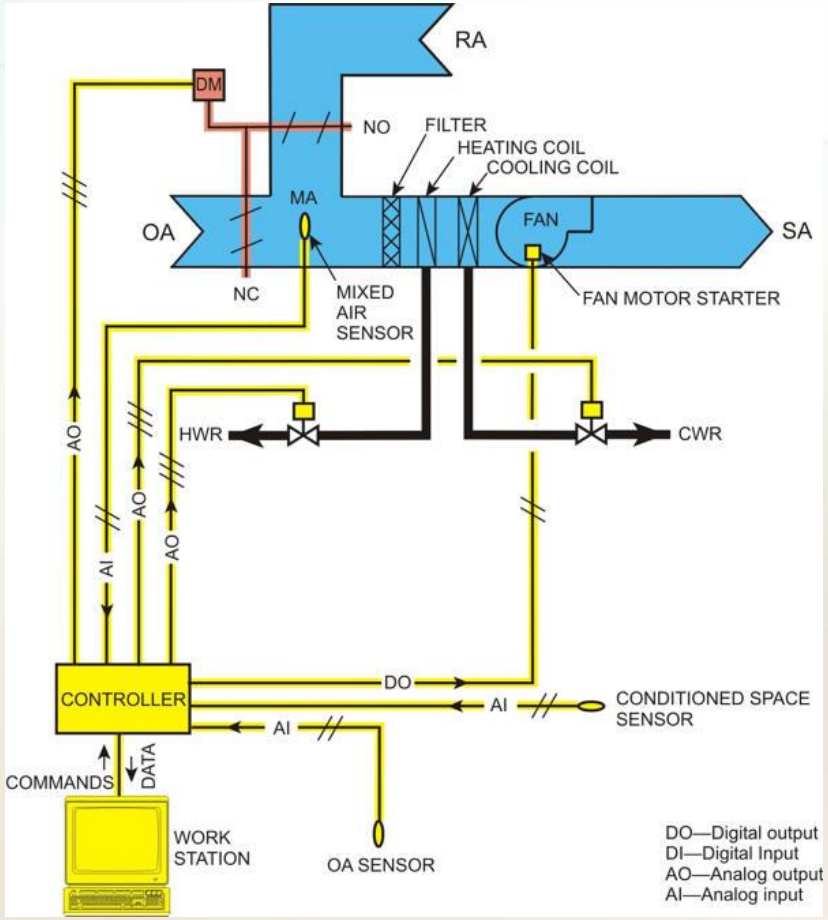
TAB Responsibilities When Not Specified

- Confirm that the sequences of operation for all control modes are in compliance with the final approved control submittal.

- UPON LOSS OF POWER TO THE CONTROL SYSTEM THE FAN SHALL CONTINUE TO OPERATE AND THE COOLING COIL CONTROL VALVE SHALL REMAIN IN ITS CURRENT POSITION.
- UPON A DROP IN COOLING COIL INLET AIR TEMPERATURE BELOW THE FREEZESTAT (LOCATED ON THE DISCHARGE SIDE OF THE PREHEAT COIL) SET POINT (40° F ADJUSTABLE), AN ALARM CONDITION SHALL BE INDICATED TO THE HVAC CONTROL SYSTEM. THE CHILLED WATER VALVE SHALL MODULATE TO THE FULLY OPEN POSITION. UPON A FURTHER DROP IN AIR TEMPERATURE BELOW THE FREEZESTAT (LOCATED AT THE SUPPLY FAN INLET) SET POINT (33°F ADJUSTABLE), A SECOND ALARM SIGNAL SHALL BE INDICATED TO THE HVAC CONTROL SYSTEM. THE UNIT SHALL ENTER STOP MODE AND THE O.A. DAMPER SHALL CLOSE.

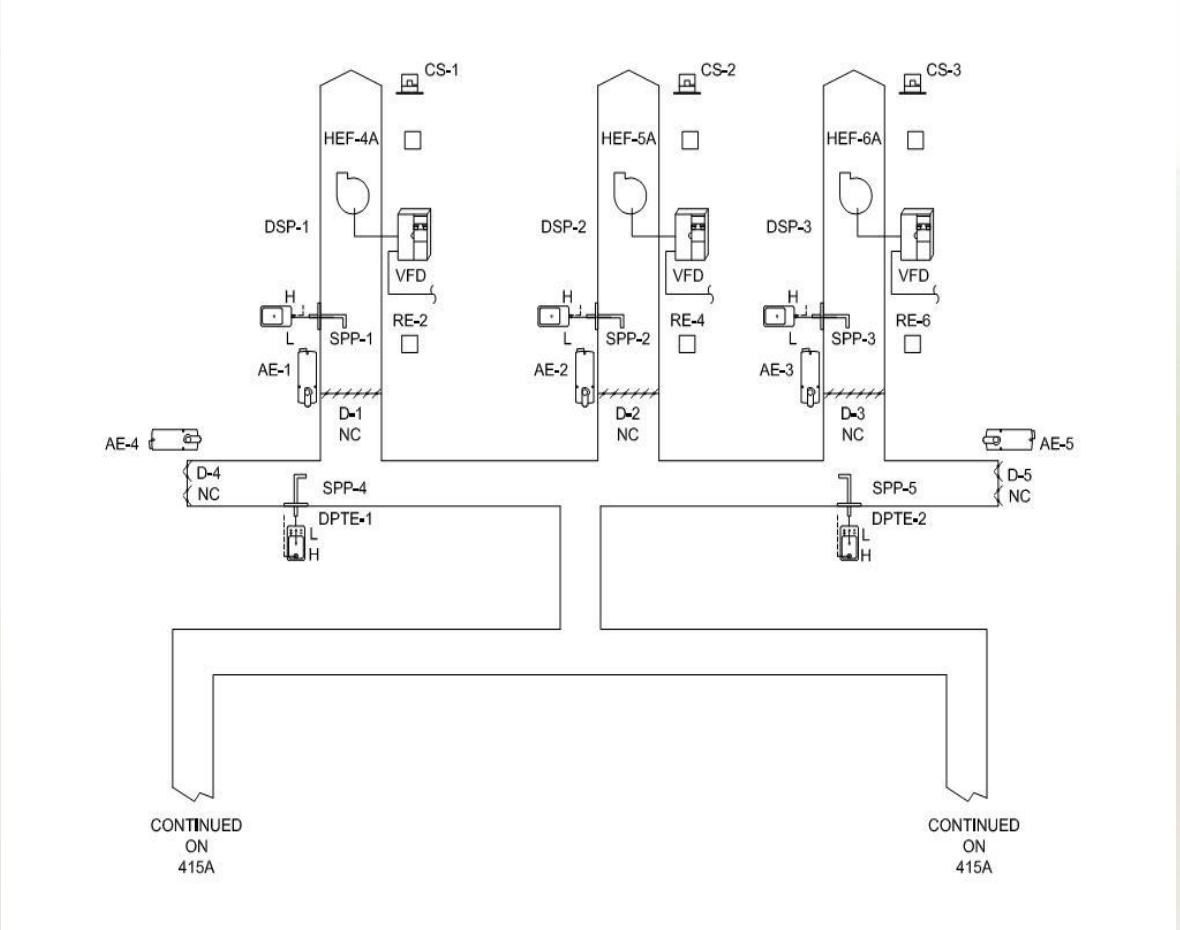
TAB Responsibilities When Not Specified

- Verify the settings and operation of end switches, pressure-electric switches, solenoid valves, contactors, etc.



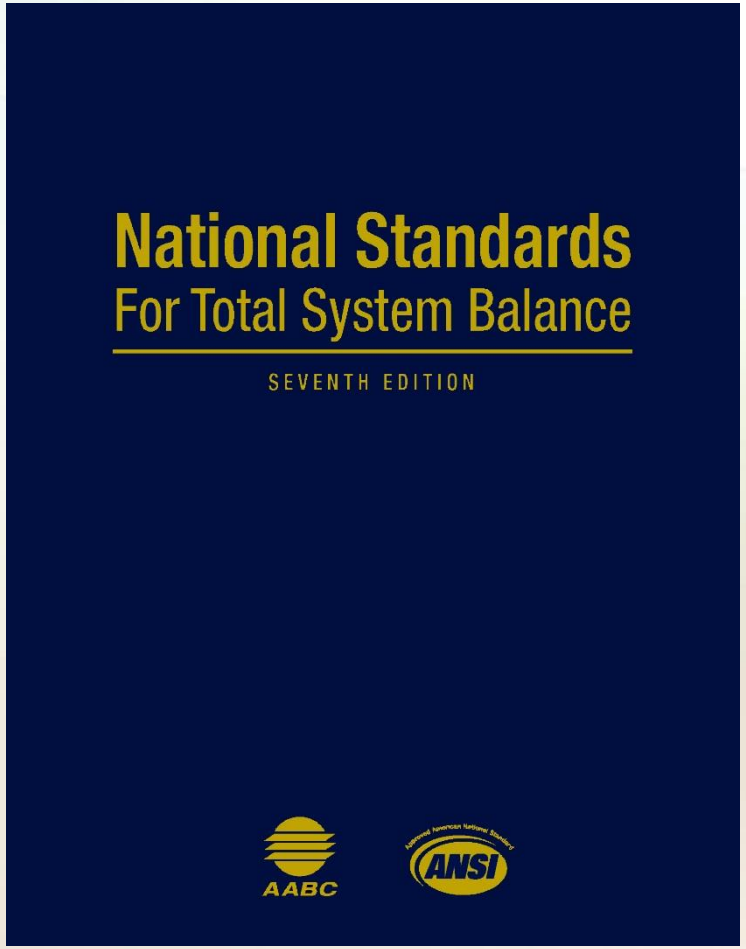
TAB Responsibilities When Not Specified

- Check the operation of lockout or interlock systems.



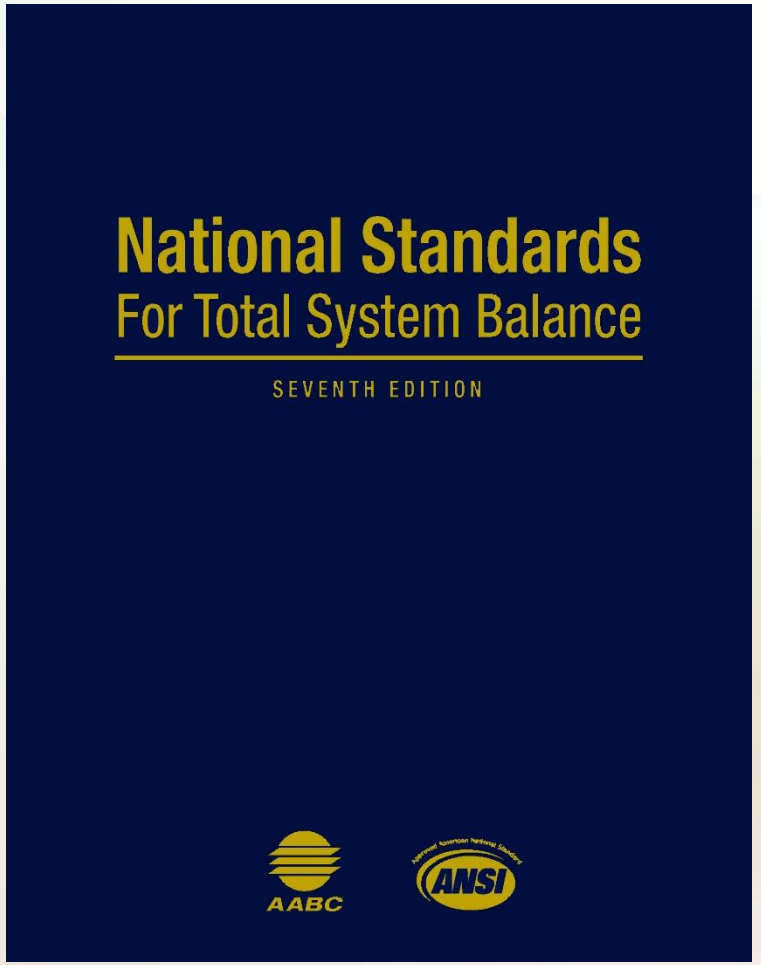
Verification When Specified

- When design documents require *Total System Balancing* or written verification of controls, everything discussed on the previous slides must be documented.



Verification When Specified

- Chapter 12, Section 3, of the ANSI/AABC National Standards For Total System Balancing covers Verification and Documentation. This section lists control sequences for Air Handling Units, Fan Systems and Hydronic Systems. It also covers Component Calibration, Point Verification and Dynamic Testing.



Case Study of a VAV Air Handling Unit

- Specification
- Equipment Control Points
  - Supply Air Temperature- AI
  - Supply Air Static Pressure- AI
  - CO_2- AI
  - Fan Status- DI
  - Static Pressure High Limit- DI
  - Fan Start/Stop- DO
  - Fan Speed Control- AO
  - Chilled Water Valve Control- AO
  - OA Damper Control- AO

- Specification continued
- Fan Control- When the air handling unit is requested to run, the BAS shall start the fan. A current switch shall prove status to the BAS and shall alarm at the central site if the switch is not made within 40 seconds (adjustable).
- Cold Deck Temperature Control- When the air handling unit is in occupied mode and cooling is required, the BAS shall send a request for cooling to the chiller plant and shall modulate the chilled water control valve to maintain leaving air temperature setpoint (55°F, adjustable)

Case Study of a VAV Air Handling Unit

- Specification continued
- Air Volume Control- While the air handling unit is active, the BAS shall maintain the duct static pressure setpoint at 1.5 inch w.g. (adjustable, final setpoint to be determined by TAB contractor) by modulating the speed of the supply fan through a variable speed drive (VSD). A static pressure sensor, mounted two thirds down the longest duct run shall monitor the static pressure of the supply ducts. If the duct static pressure rises above 3.0 inches w.g. (locally adjustable) the air handling unit shall be de-energized via hardwire interlock to the VSD safety circuit.

- Specification continued
- The BAS shall monitor the high static limit switch and shall display and alarm at the central site. The static pressure high limit switch must be manually reset.
- Demand Control Ventilation- When the air handling unit is running an occupied mode, the OA damper control shall be enabled. CO_2 sensors mounted as indicated on the drawings shall monitor the CO_2 levels. Where multiple sensors are provided for a particular AHU, the BAS shall select the highest level for control. The BAS shall modulate the outdoor damper from its

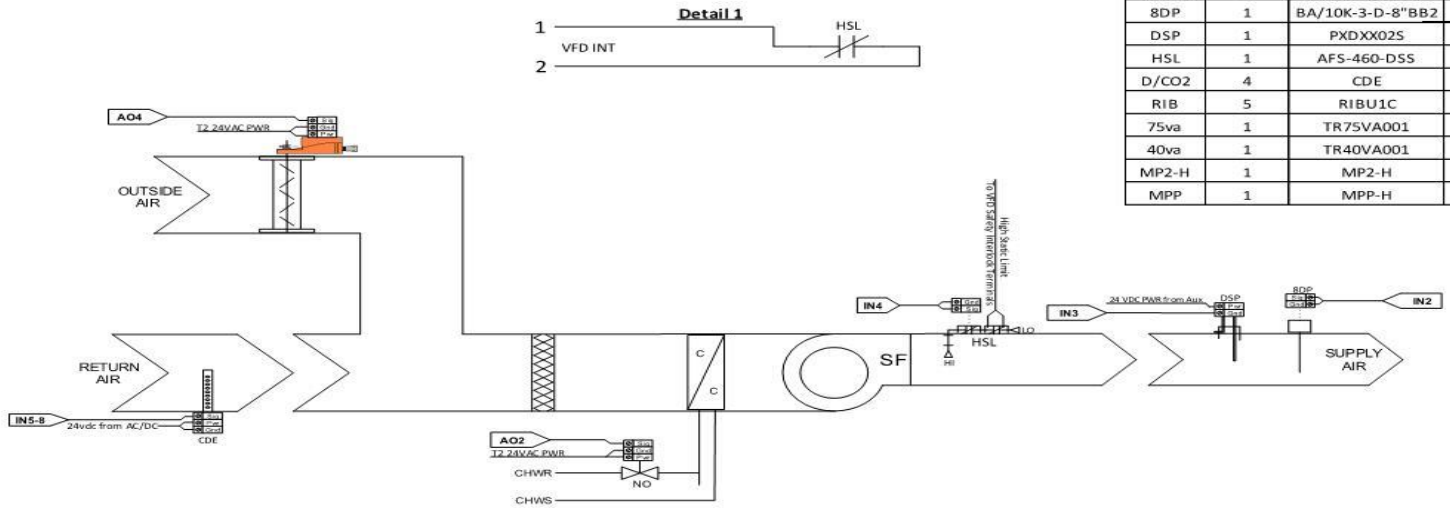
Case Study of a VAV Air Handling Unit

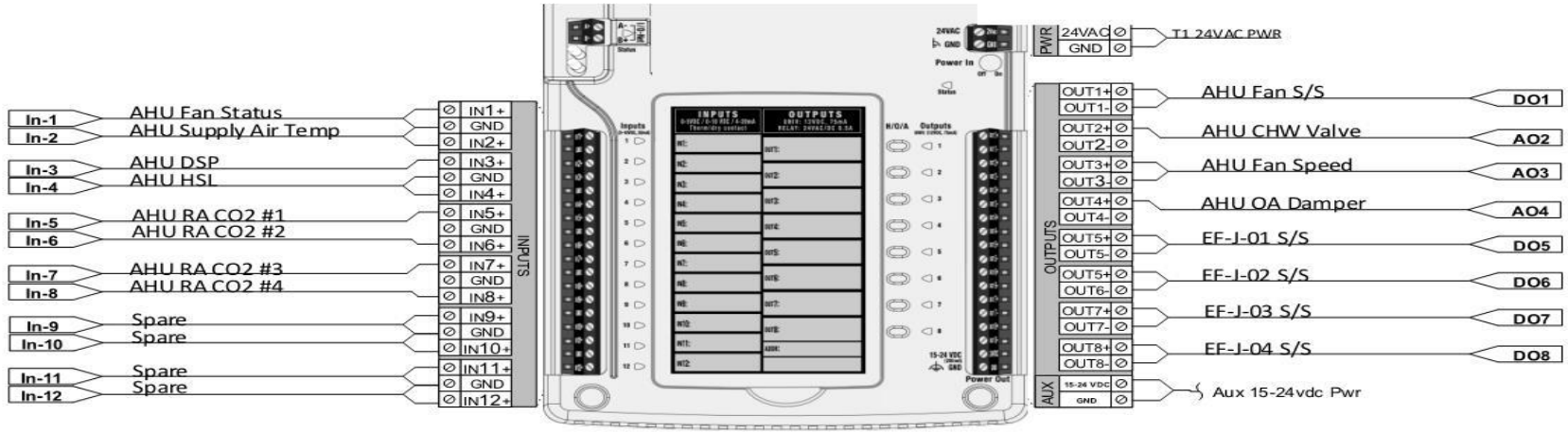
- Specification continued
- minimum position to its maximum position as required to maintain the CO_2 level between 850 ppm and 1000 ppm (all adjustable). The OA dampers minimum and maximum positions shall be determined by the TAB contractor to be the positions that allow the scheduled minimum and maximum OA CFM. The system shall have the ability to perform a “Purge Mode” at a scheduled time for a scheduled duration.

- Specification continued
- Associated Equipment- During the occupied time period, any associated exhaust fans shall be energized.

Case Study of a VAV Air Handling Unit

Bill of Material			
Item	Quantity	Part Number	Description
Status	1	CSCGFN150NN	Split Core Current Switch
8DP	1	BA/10K-3-D-8"BB2	8" Duct Probe
DSP	1	PXDXX02S	Duct Static Pressure Trans
HSL	1	AFS-460-DSS	High duct static limit switch
D/CO2	4	CDE	Duct CO2 Sensor
RIB	5	RIBU1C	VAC/DC Coil 10 Amp Rib Relay
75va	1	TR75VA001	75VA Transformer
40va	1	TR40VA001	40VA Transformer
MP2-H	1	MP2-H	Mach-Pro 2 HOA
MPP	1	MPP-H	Mach-Pro Point HOA





Tracking Static Pressure Controllers with an Airflow Profile

EAB BOX NUMBER	TERMINAL UNIT TAG NUMBER	MAXIMUM				MINIMUM				REMARKS
		DESIGN CFM	ACTUAL CFM	ACTUAL DISPLAY CFM	ACTUAL DAMPER POSITION %	DESIGN CFM	ACTUAL CFM	ACTUAL DISPLAY CFM	ACTUAL DAMPER POSITION %	
1	CVB-J-04-05	790	770	790	65	200	200	200	-	
2	CVB-J-04-06	870	875	870	77	220	215	220	-	
3	CVB-J-04-01	1200	1120	1200	77	300	295	300	-	
4	CVB-J-04-04	1135	1115	1135	90	285	270	285	-	
5	CVB-J-04-03	2010	2065	2010	79	500	500	500	-	
6	CVB-J-04-02	2010	2095	2010	83	500	510	500	-	
	TOTAL	8015	8040	8015		2005	1990	2005		
Box(es) not in control at time of test:		-			VFD Hertz:	53.4		Final Maximum Static Pressure Setpoint:		+0.43 " w.c.
Box(es) closed for diversity (if applicable):		-			Diversity CFM:	-		Final Minimum Static Pressure Setpoint:		- " w.c.

Terminal Unit Control Configuration & Sequence Verification

EAB TERMINAL UNIT NUMBER	Box 1	Box 2	Box 3	Box 4	Box 5	Box 6
EQUIPMENT TAG	CVB-J-04-05	CVB-J-04-06	CVB-J-04-01	CVB-J-04-04	CVB-J-04-03	CVB-J-04-02
CONTROL SYSTEM NAME	CVB-J-04-05	CVB-J-04-06	CVB-J-04-01	CVB-J-04-04	CVB-J-04-03	CVB-J-04-02
CONTROL SYSTEM ADDRESS	3093212	3093213	3093208	3093211	3093210	3093209
SETPOINT CFM (MAX / MIN)	790 / 200	870 / 220	1200 / 300	1135 / 285	2010 / 505	2010 / 505
ACTUAL CFM (MAX / MIN)	770 / 200	875 / 215	1120 / 295	1115 / 270	2065 / 500	2095 / 510
DISPLAY CFM (MAX / MIN)	790 / 200	870 / 220	1200 / 300	1135 / 285	2010 / 505	2010 / 505
INLET SIZE	10	10	12	12	14	14
DIRECTION TO CLOSE	CW	CW	CW	CW	CW	CW
MAX VELOCITY PRESSURE (INCHES W.C.)	0.27	0.37	0.29	0.27	0.46	0.42
MIN VELOCITY PRESSURE (INCHES W.C.)	0.018	0.022	0.020	0.016	0.027	0.27
CAL-K (COEFFICIENT)	0.70	0.65	0.69	0.70	0.70	0.72
DEADBAND	10% Tested at 0CFM	10% Tested at 0CFM	10% Tested at 0CFM	10% Tested at 0CFM	10% Tested at 0CFM	10% Tested at 0CFM
HOT WATER VALVE (%)	0-100	0-100	0-100	0-100	0-100	0-100
ECM MOTOR VOLTAGE (VOLTS)	(1)	(1)	(1)	(1)	(1)	(1)
ZERO FLOW	OK	OK	OK	OK	OK	OK
CONTROL SEQUENCE TYPE (SEE SEQUENCE SUMMARY)	A	A	A	A	A	A
DATE OF INITIAL UNIT VERIFICATION	6-9-16	6-9-16	7-16-16	7-16-16	6-9-16	6-9-16
DATE OF CONTROL SEQUENCE VERIFICATION	6-9-16	6-9-16	7-16-16	7-16-16	6-9-16	6-9-16

Terminal Box Control Sequence Verification “A”

1.0	**GENERAL DESCRIPTION**
1.1	The Series Fan Powered Variable Air Volume terminal unit (CVB) is pressure independent and controlled by a DDC controller. The CVB consists of a modulating damper primary damper, airflow sensor, an ECM motor a hot water coil and a space mounted temperature sensor. The CVB shall be controlled by a local BAS controller.
2.0	**AIRFLOW AND TEMPERATURE CONTROL**
2.1	When the zone becomes active, the BAS controller shall determine based on space temperature, whether heating or cooling is required. If cooling is required, the CVB damper shall be modulated open to its maximum cooling CFM setpoint and a run signal shall be sent to the air handling unit serving the terminal unit. As the space temperature returns to setpoint, the VAV damper shall modulate to its minimum cooling CFM setpoint (25% of maximum). If heating is required, the CVB terminal damper shall remain at its minimum CFM setpoint and the reheat valve shall be modulated to maintain the heating setpoint.
2.2	Verify the ability of the VAV to maintain the space temperature setpoint.
2.3	Increase the space temperature by 2° F above the cooling setpoint. Verify the VAV damper modulates open to its maximum CFM setpoint.
2.4	Decrease the space temperature back to the space temperature setpoint. Verify the VAV damper modulates closed to its minimum CFM setpoint.

Terminal Box Control Sequence Verification “A”

2.5	Decrease the space temperature by 2° F below the heating setpoint. Verify the heating water valve modulates open to maintain the heating setpoint.
2.6	Decrease the space temperature back to the space temperature setpoint. Verify the heating water valve modulates closed.
3.0	**OCCUPANCY CONTROL**
3.1	During building occupied periods, the CVB shall monitor the status input with an infrared occupancy sensor in the space. When the occupancy sensor detects an unoccupied room, the BAS shall enter the occupied vacant state, which will adjust the cooling temperature setpoint up and the heating temperature down by 3°F respectively.
3.2	Verify the room cooling and heating setpoint is adjusted up and down by 3°F respectively.

Terminal Box Control Sequence Verification “A”

3.0	**UNOCCUPIED CONTROL**
3.1	During unoccupied periods, the VAV damper shall be closed. If the space temperature reaches the unoccupied heating or cooling temperature setpoint (55°F and 95 °F, adj.), the VAV shall be enabled and the damper shall modulate open to maintain setpoint.
3.2	Verify the ability of the VAV to maintain the space temperature setpoint in unoccupied mode.
3.3	Verify the VAV is in unoccupied mode.
3.4	Verify the VAV is disabled and the damper is closed.
3.5	Adjust the space temperature above 95°F. Verify the VAV is enabled and the damper modulates open.
3.6	Verify the VAV is in unoccupied mode.
3.7	Adjust the space temperature below 55°F. Verify the VAV is enabled and the damper modulates open.

Sensor Calibration Verification Data

UNIT NUMBER	DDC POINT	DDC POINT DESCRIPTION	ACTUAL VALUE	DDC VALUE	DDC OFFSET	DATE
AHU-J-04	STAT	Fan Status	On/Off	On/Off	N/A	7-11-16
AHU-J-04	CDT	Cooiling Coil Temperature	54.2	53.2	+1.0	7-11-16
AHU-J-04	STP	Supply Static Pressure	0.43	0.43	0.0	7-11-16
AHU-J-04	HSL	High Static Pressure	Normal/Alarm	Normal/Alarm	N/A	7-11-16
AHU-J-04	RA-CO2-1	Return CO2-1	450	500	-50	7-11-16
AHU-J-04	RA-CO2-2	Return CO2-2	440	490	-50	7-11-16
AHU-J-04	RA-CO2-3	Return CO2-3	445	505	-50	7-11-16
AHU-J-04	RA-CO2-4	Return CO2-4	406	507	-100	7-11-16
AHU-J-04	S/S	Fan Command	On/Off	On/Off	N/A	7-11-16
AHU-J-04	CHWV	Chilled Water Valve	0-100	0-100	N/A	7-11-16
AHU-J-04	SPEED	VFD Command	0-100	0-100	N/A	7-11-16
AHU-J-04	OAD	Outside Air Damper	0-100	0-100	N/A	7-11-16
CVB-J-04-05	TSTAT	Room Temperature	70.0	70.1	+0.5	6-9-16
CVB-J-04-05	SAT	Supply Air Temperature	65.7	65.8	-0.5	6-9-16
CVB-J-04-06	TSTAT	Room Temperature	70.3	70.5	+1.0	6-9-16
CVB-J-04-06	SAT	Supply Air Temperature	65.8	65.8	-0.5	6-9-16
CVB-J-04-01	TSTAT	Room Temperature	68.4	68.4	-1.5	7-16-16
CVB-J-04-01	SAT	Supply Air Temperature	51.9	51.6	-1.5	7-16-16
CVB-J-04-04	TSTAT	Room Temperature	67.3	67.1	-1.5	7-16-16
CVB-J-04-04	SAT	Supply Air Temperature	53.4	53.4	+0.5	7-16-16
CVB-J-04-03	TSTAT	Room Temperature	72.5	72.7	-0.5	6-9-16
CVB-J-04-03	SAT	Supply Air Temperature	65.0	64.8	-1.0	6-9-16
CVB-J-04-02	TSTAT	Room Temperature	72.5	72.7	-0.5	6-9-16
CVB-J-04-02	SAT	Supply Air Temperature	67.4	67.3	+1.0	6-9-16

AHU Control Sequence Verification Data

ITEM #	CONTROL SEQUENCE	DATE
1.0	**GENERAL DESCRIPTION**	
1.1	Air Handling Unit (AHU-J-04) consisting of an outside air damper, a pre-filter section, a chilled water cooling coil with modulating control valve, and a supply fan controlled by a dedicated variable frequency drive (VFD). The AHU shall be started, stopped, and controlled via a dedicated controller. The AHU serves variable volume single duct terminal units as well as variable volume primary fan powered terminal units.	
2.0	**AHU START COMMAND**	
2.1	The AHU supply fan shall be controlled by the VFD through either BAS control or local override. The VFD shall be energized by an HOA switch. With the HOA switch in the auto position, the AHU shall be started and stopped through the BAS. Upon a start command, the BAS controller shall energize the VFD. AHU supply fan status shall be proven to the BAS via current sensors installed in the VFD. Upon proof of AHU supply fan status, the BAS controller shall initiate temperature and static pressure PID control loops. A request for cooling shall be sent to the chilled water system. Any associated exhaust fans shall be energized when the AHU is in occupied mode.	

AHU Control Sequence Verification Data

ITEM #	CONTROL SEQUENCE	DATE
2.2	AHU is in “Occupied” mode.	8-23-16
2.3	Verify the VFD is energized.	8-23-16
2.4	Verify the AHU is ON and indicated ON by the BAS.	8-23-16
2.5	Verify the static pressure control loop is enabled.	8-23-16
2.6	Verify the discharge air temperature control loop is enabled.	8-23-16
2.7	Verify the outside air damper is modulated open.	8-23-16

AHU Control Sequence Verification Data

ITEM #	CONTROL SEQUENCE	DATE
3.0	**AHU STOP COMMAND**	
3.1	With the VFD HOA switch in the auto position, the AHU shall be stopped through the BAS. When the AHU is commanded to stop, the VFD shall be de-energized, the outside air damper shall be commanded closed, and any associated exhaust fans shall be de-energized. The BAS shall disable the temperature and static pressure control loops.	
3.2	AHU is in “Unoccupied” mode.	8-23-16
3.3	Verify the VFD is de-energized.	8-23-16
3.4	Verify the AHU status is OFF and indicated OFF in the BAS.	8-23-16
3.5	Verify the outside air damper is closed.	8-23-16
3.6	Verify that any associated exhaust fans are de-energized.	8-23-16
3.7	Verify that the static pressure and temperature control loops are disabled.	8-23-16

AHU Control Sequence Verification Data

ITEM #	CONTROL SEQUENCE	DATE
4.0	**TEMPERATURE CONTROL – CHILLED WATER COIL**	
4.1	The AHU shall be equipped with a chilled water coil. The flow is regulated by a modulating control valve. A discharge air temperature sensor installed after the coil shall provide an input to the BAS which will modulate the chilled water valve to maintain the discharge air temperature setpoint. (55 deg. F, adj.)	
4.2	Verify the temperature control loop by adjusting the discharge air temperature setpoint and observing the ability of the BAS to control the AHU discharge air temperature to the new setpoint.	8-23-16
4.3	Override the discharge air temperature setpoint 5 degrees above the current setpoint. Verify the chilled water valve modulates closed.	8-23-16
4.4	Override the discharge temperature setpoint 10 degrees below the current setpoint. Verify the chilled water valve modulates open.	8-23-16
4.5	Release the discharge air temperature setpoint back to its original value. Verify the chilled water valve modulates to maintain setpoint.	8-23-16

AHU Control Sequence Verification Data

ITEM #	CONTROL SEQUENCE	DATE
5.0	**STATIC PRESSURE CONTROL**	
5.1	The AHU is equipped with a differential pressure sensor located approximately 2/3 down the longest supply air duct. The BAS shall monitor the duct static pressure and modulate the fan speed through the VFD to maintain the static pressure setpoint. (1.5 i.w.c., adj.)	
5.2	Verify the static pressure control loop by adjusting the static pressure setpoint and observing the ability of the BAS to control the AHU VFD to maintain setpoint.	8-23-16
5.3	Override the static pressure setpoint 0.5 i.w.c. above the current setpoint. Verify the VFD increases the supply fan speed to maintain the new setpoint.	8-23-16
5.4	Override the static pressure setpoint 1.0 i.w.c. below the current setpoint. Verify the VFD decreases the supply fan speed to maintain the new setpoint.	8-23-16
5.5	Release the static pressure setpoint to its original value. Verify the VFD modulates the supply fan speed to maintain setpoint.	8-23-16

AHU Control Sequence Verification Data

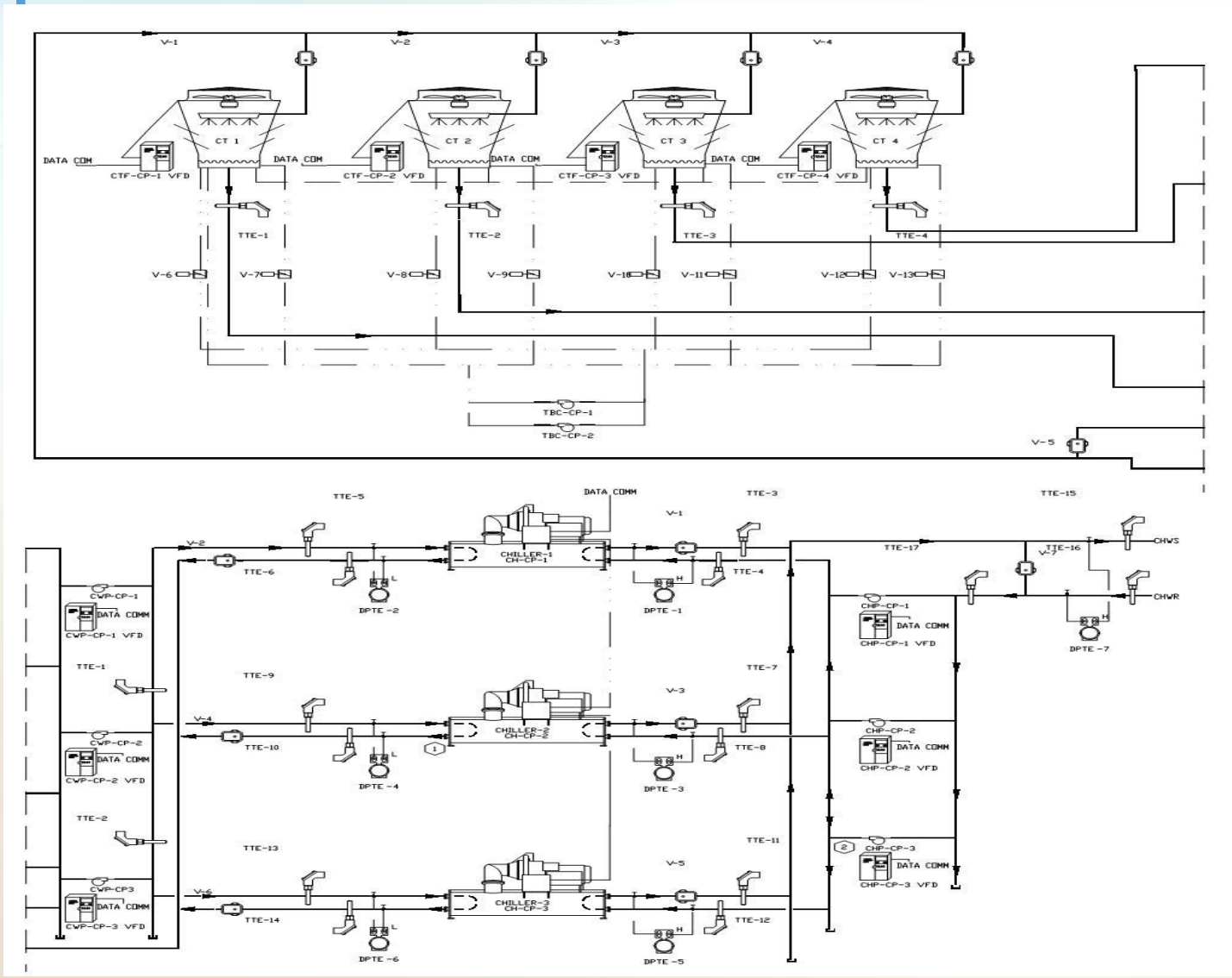
ITEM #	CONTROL SEQUENCE	DATE
6.0	**OUTSIDE AIR CONTROL**	
6.1	The AHU is equipped with a CO2 sensor mounted in the return air ductwork that monitors CO2 levels in the space. The BAS shall monitor the CO2 level and modulate the outside air damper to maintain the CO2 level setpoint (between 850 ppm and 1000 ppm, all adj.). When multiple CO2 sensors are provided for a particular AHU, the BAS shall select the highest level for control.	8-23-16
6.2	Verify the outside air control loop by adjusting the CO2 level setpoint and observing the ability of the BAS to modulate the outside air damper to maintain setpoint.	8-23-16
6.3	Override the CO2 setpoint 500 ppm above the current setpoint. Verify the outside air damper modulates closed.	8-23-16
6.4	Override the CO2 setpoint 300 ppm below the current setpoint. Verify the outside air damper modulates open.	8-23-16
6.5	Release the CO2 setpoint to its original value. Verify the outside air damper modulates to maintain setpoint.	8-23-16

AHU Control Sequence Verification Data

ITEM #	CONTROL SEQUENCE	DATE
7.0	**ALARMS AND SAFETIES**	
7.1	The AHU shall be equipped with a high static limit switch installed at the discharge of the AHU to monitor the static pressure of the supply duct. If the duct static pressure rises above the setpoint (3.0 i.w.c., adj.), the AHU shall be de-energized and an alarm shall be generated in the BAS. After a high static condition, the high limit switch must be manually reset for the AHU to be enabled.	
7.2	Simulate a high static condition by applying pressure to the high limit switch.	8-23-16
7.3	Verify the AHU is de-energized.	8-23-16
7.4	Verify an alarm is annunciated in the BAS.	8-23-16
7.5	Manually reset the high limit switch and verify the AHU is enabled.	8-23-16

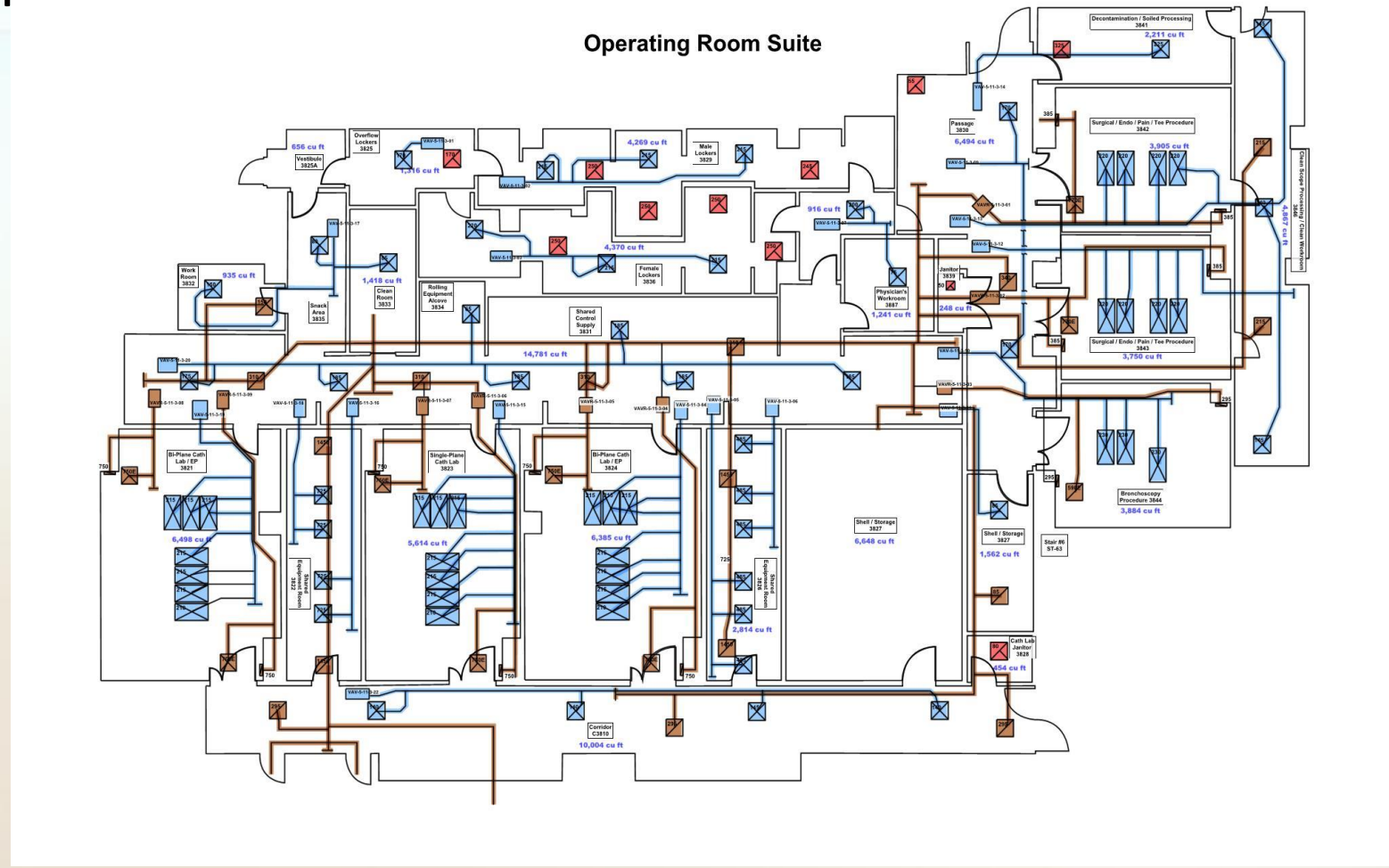
Control Sequence Verification

- Fan systems and hydronic systems control sequence verification and component calibration are performed in a similar manner as the case study presented



Control Sequence Verification

- Complex laboratory, hospital or smoke control requires more time to analyze the pressure barriers and sequences but the overall process is the same.



Questions / Conclusion

Question

The main question that needs to be asked is: If the air and hydronic systems are balanced to 5%, will the system work if the controls are not verified?

Conclusion

Thank You For Your Time!