AABC Commissioning Group

AIA Provider Number 50111116

TAB & Commissioning Working Together: Verifying Control Systems

AIA Course Number CXENERGY1530

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ENGINEERED AIR BALANCE

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Course Description

Complete verification testing of control systems is a key aspect of a fully commissioned building, but one that is not always done in a comprehensive way. This informative session will explain the importance of 100% verification of these crucial systems, 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

At the end of the this course, participants will be able to:

1. Understand who completes verification testing of control systems, which is essential to a successfully commissioned building.

2. Learn how test and balance professionals and commissioning authorities can work as a team to perform necessary testing and verification.

3. Understand the documentation required when performing verification testing of control systems.

4. Learn how buildings fail to meet design objectives when complete verification testing of control systems is not performed in a comprehensive way.

The Commissioning Process for HVAC Systems

1. Design Phase Activities (Pre-Construction)
2. Construction Phase Activities (Pre-TAB)
3. Testing, Adjusting and Balancing
4. Acceptance Phase Activities (Functional Performance Testing)
5. Occupancy Phase Activities (Measurement and Verification)

The Commissioning Process for HVAC Systems

Design Phase Activities ï Critical Items

1. Commissioning and TAB Specifications
2. Control Sequences, Schematics and Specifications
3. Owner's Operational Requirements
4. Equipment Accessibility for Testing and Maintenance
5. Owner Training Requirements

The Commissioning Process for HVAC Systems

Design Phase Activities ï Critical Items

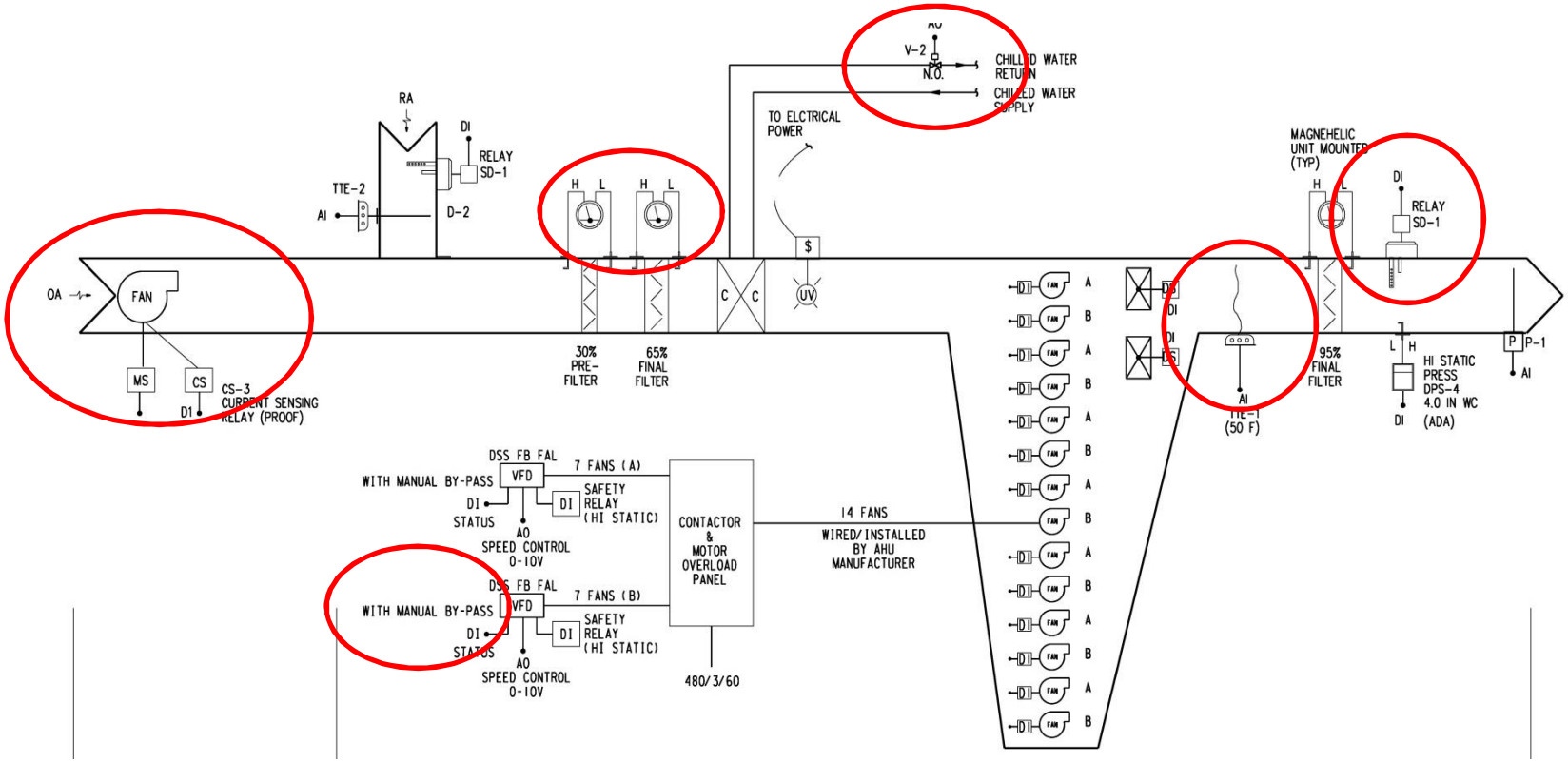
Do the contract drawings and specifications indicate the appropriate components and controls necessary for a functioning sequence of operations for each system?

Common Oversights:

1. Averaging vs. Single Point Sensors
2. Equipment Status Monitoring
3. Safeties
4. Control and Isolation Dampers / Valves
5. Pressure Sensor Quantity and Locations
6. Local or Hand operation of Equipment
7. Piping and Ductwork testing ports (Peteês Plugs)

The Commissioning Process for HVAC Systems

What is wrong with this picture?



The Commissioning Process for HVAC Systems

Design Phase Activities ï Critical Items

Do the specifications indicate performance requirements for the control system?

Common Oversights:

1. Specified Sensor Accuracy
2. Acceptable Calibration Ranges for Sensors (Field Instrument Accuracy)
3. PID Control Loop Tuning Parameters
4. Use of Adaptive PID Control Loops
5. Sensor Control Signal Resolution

This would typically be part of the Commissioning Authorityôs review, but should be reviewed by the TAB Firm also.

The Commissioning Process for HVAC Systems

Design Phase Activities ï Critical Items

Do the contract drawings and / or specifications indicate the requirements for coordination between the Controls Contractor, CxA and the TAB Firm?

Common Oversights:

1. Proprietary Software availability
2. Hardware Interface modules
3. Licensing requirements for Operatorôs Workstation (GUI)
4. Control Technician assistance with TAB and Cx activities

The TAB Firm and Commissioning Authority should be reviewing these requirements and providing comments or questions. This is critical to smooth TAB and Functional Testing later in the project.

The Commissioning Process for HVAC Systems

Construction Phase Activities ï Critical Items

Control Vendor Shop Drawings (CxA Submittal Review):

1. Do the sequences of operation and schematics indicate all of the components shown in the contract drawings?
2. Does the Bill of Material indicate the correct sensors and components as well as the appropriate quantity to meet specification requirements?
3. Averaging sensors may not be long enough to achieve sufficient coverage with one sensor. The specs may dictate a coverage requirement.
4. Do the Control Point names and System Architecture match the requirements in the specifications?
5. Are termination schedules included for clear direction to the low voltage electrician?

The Commissioning Process for HVAC Systems

Construction Phase Activities ï Critical Items

Control Vendor Product Data (CxA Submittal Review):

1. Do the control devices meet the requirements in the project specifications?
2. Are the devices compatible with the intended application?
3. Do user interface devices (i.e.. thermostats, override switches) have the features necessary to accomplish the intended sequences of operation?
4. Do sensor accuracies and resolutions meet the requirements in the project documents? What will be the field verification accuracy? (**The TAB Firm should have a detailed understanding of this information.)**

The Commissioning Process for HVAC Systems

Construction Phase Activities ï Critical Items

Point Type	Project Spec. Required Accuracy	Submitted Accuracy	Max Offset Allowed	Remarks
Chilled Water Temperature	+/- 0.5ęF	Model TE-631AM-1: +/- 0.34ęF	1.0	
Room Temperature	+/- 0.5ęF	+/- 1ęF	1.0	
Duct Temperature	+/- 0.5ęF	Ret. Air Model TE-6311P-1: +/- 0.34ęF OA, MA, CC, SA-T Model TE-6316P-1: +/- 3.4ęF	1.0	
All other temperatures	+/- 0.75ęF		2.0	
Humidity	2% general applications, 1% for process control	Model HE-67P2-0N00P: +/- 2%	3%	

The Commissioning Process for HVAC Systems

Construction Phase Activities ï Critical Items

Control Vendor Product Data (CxA Submittal Review):

Airflow Measurement Station Considerations

1. Were the airflow measurement stations sized based upon the contract drawings and scheduled airflow?
2. Airflow station performance should be evaluated within the manufacturerôs recommendations from the minimum to maximum airflow range as the sensor will be OPERATED (not Scheduled)
3. Sizes should be carefully coordinated with the ductwork shop drawings for proper sizing, placement and verification by the TAB firm.
4. Is the control signal range and resolution appropriate for the intended airflow range?

The Commissioning Process for HVAC Systems

Construction Phase Activities ï Critical Items

Control Vendor Product Data (CxA Submittal Review):

Control Valves / Dampers

1. Verify CV values and sizing based upon intended operating flows, NOT line pipe sizing.
2. Confirm maximum pressure requirements meet the specification and actuators have sufficient torque for the intended application.
3. Confirm pressure differential requirements for pressure independent devices. (TAB Firm must review these requirements)
4. Verify failure criteria (i.e.. spring return, normally open, normally closed etc.) is consistent with the intended sequence of operations.
5. Verify the proper control signal and resolution can be achieved per the requirements in the project documents.

The Commissioning Process for HVAC Systems

Construction Phase Activities ï Installation Verification

During site visits, observe controls installation progress:

1. Sensor locations and routing (note on drawings for future reference by TAB and Cx personnel)
2. Appropriate test ports are installed and accessible to verify sensor calibration (TAB should verify)
3. Safety sensor locations and wiring (hardwire safety interlocks)
4. Fire Alarm components and interfaces
5. Duct Mounted Smoke detector installation and locations
6. Fire Alarm addressable relays for equipment shutdown
7. Smoke Control systems

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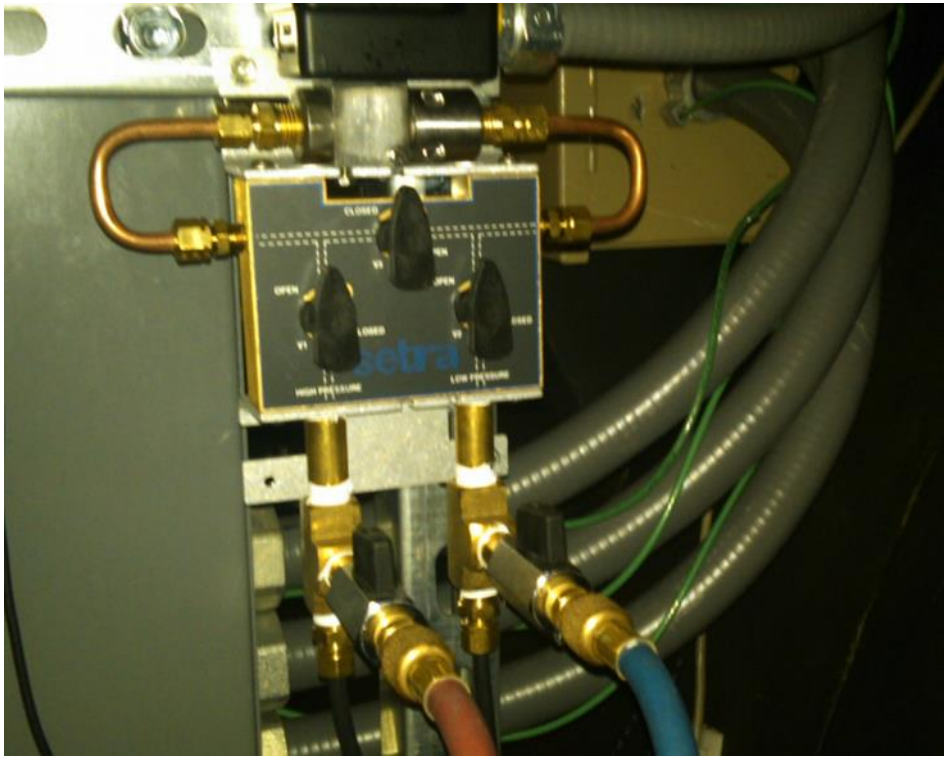
Construction Phase Activities ï Installation Verification

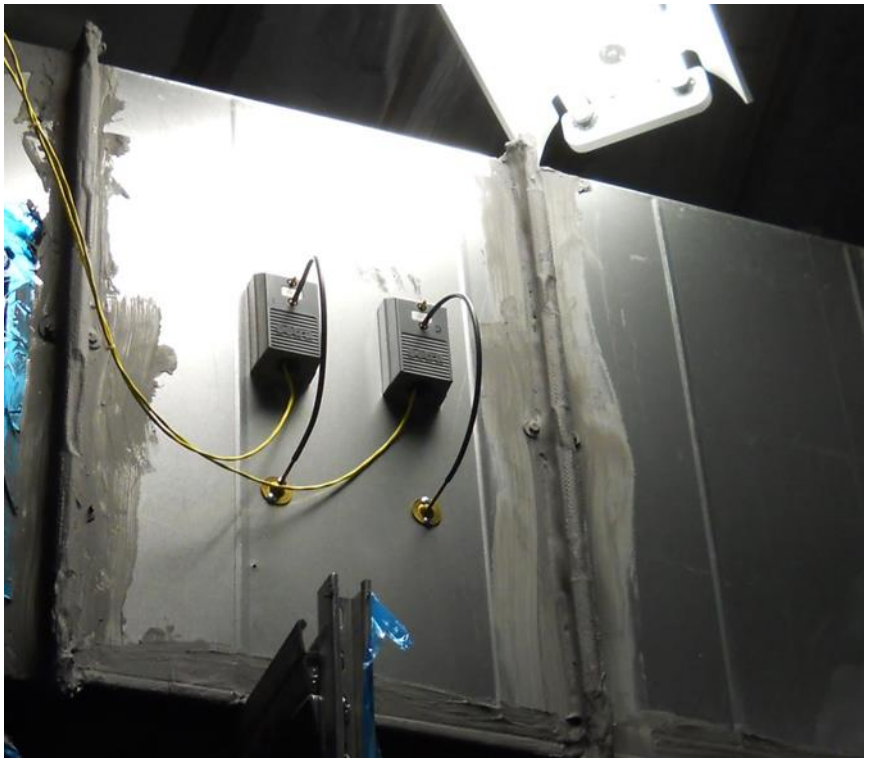


The Commissioning Process for HVAC Systems

Construction Phase Activities ï Installation Verification

The Commissioning Process for HVAC Systems

Construction Phase Activities ï Installation Verification



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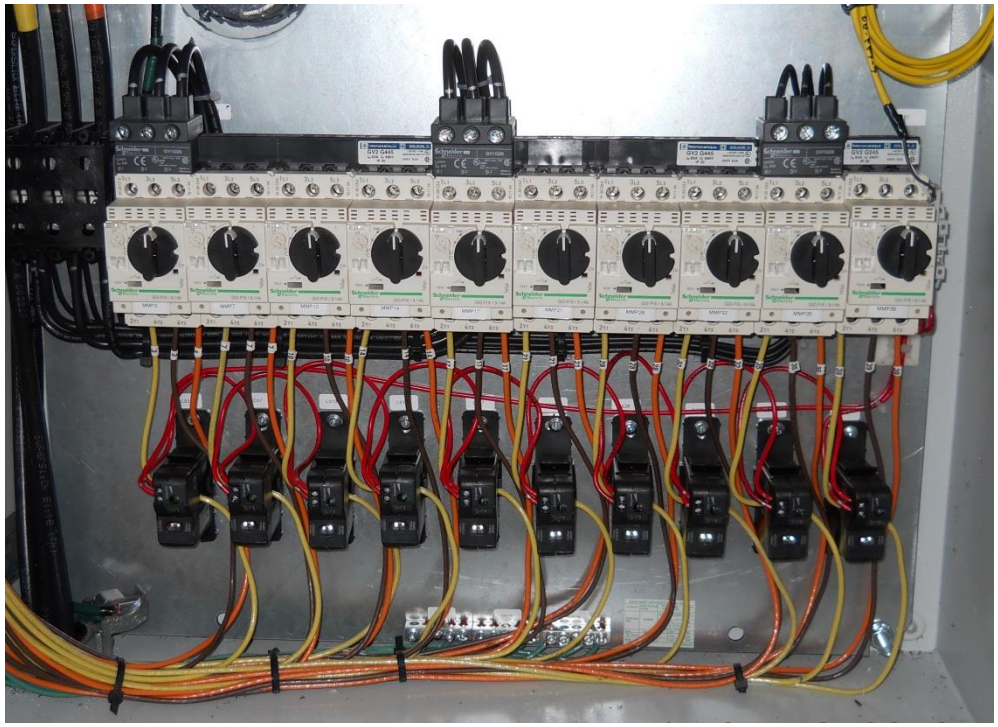
Construction Phase Activities ï Installation Verification



The Commissioning Process for HVAC Systems

Construction Phase Activities ï Installation Verification

The Commissioning Process for HVAC Systems

Construction Phase Activities ï Controls Coordination

1. Can software be loaded onto the TAB Technicianôs or CxAôs laptop or will the control vendor furnish a licensed laptop?
2. Is a ñBalancing Toolò available?
3. Does the TAB Technician or CxA require full time support from the Controls Tech?
4. Is the TAB Technician or CxA proficient with the Controls Software?
5. What level of access can the TAB Technician or CxA attain? Full Edit or Read Only?
6. Does the TAB Technician or CxA have access to an Operatorôs Workstation or ñGraphical Interfaceò
7. Can the TAB technician or CxA communicate to a single piece of equipment or to the entire network?

THE ANSWERS TO THESE QUESTIONS MUST BE KNOWN BEFORE TAB AND FUNCTIONAL TESTING BEGINS

WHAT INVOLVEMENT SHOULD TAB HAVE TESTING CONTROLS

IS THE TAB AGENCY ON BOARD?

WHAT DID THE SPECIFICATION REQUIRE FOR CONTROL VERIFICATION?

DID THE TAB AGENCY INCLUDE CONTROL VERIFICATION IN THEIR PRICING OF THE PROJECT?

WHAT INVOLVEMENT SHOULD TAB HAVE TESTING CONTROLS

STANDARD REQUIREMENTS

The Associated Air Balance Council, *National Standards For Total System Balance,* requires the following:

- Work with the temperature control contractor to ensure the system is operating within the design limitations, and to obtain mutual understanding of intended control system.
- 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.
- Verify that all flow monitoring stations for air and water are properly calibrated and reading correctly.
- Verify all temperature, humidity, and pressure sensors are properly calibrated and reading correctly.
- Verify that controller setpoints meet the specification.
- Confirm that the sequences of operation for all control modes are in compliance with the final approved control submittal.

WHAT INVOLVEMENT SHOULD TAB HAVE TESTING CONTROLS

STANDARD REQUIREMENTS (Cont.)

- Verify the settings and operation of end switches, pressure-electric switches, solenoid valves, contactors, etc.
- Check the operation of lockout or interlock systems.
- Check the operation of all control valve and damper actuators. Verify the valve or damper opens and closes 100%.
- Determine that all controlled devices are properly connected.
- For a pneumatic control system, verify the operation of pilot positioners.
- Confirm that all controlled devices are operated by the intended controller.
- 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.
- Verify that all controlled devices are properly installed in the distribution system in relation to direction of flow and location.

WHAT INVOLVEMENT SHOULD TAB HAVE TESTING CONTROLS

STANDARD REQUIREMENTS (Cont.)

- Test the fail-safe modes of all controlled devices.
- Verify simultaneous heating and cooling does not occur.
- Verify all sensors are installed as shown on the contract documents.
- 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.

When the design documents require ***Total System Balancing*** or written verification of controls, the items listed above must be documented. In addition, the TAB agency shall develop a control verification and documentation plan indicating the interaction of the controls and how the systems will need to be manipulated to achieve the TSB. Submit the control plan as part of the TAB plan for review and acceptance prior to the start of the TSB process.

WHAT INVOLVEMENT SHOULD TAB HAVE TESTING CONTROLS

STANDARD REQUIREMENTS (Cont.)

Component Calibration
All temperature, pressure, and flow measuring components shall be measured and compared to the control system readout; verify and document. If the measurement is not within tolerance, the sensor will be reported to the control contractor for calibration. The following devices should be verified:

- The air temperature sensors for each heat exchanger.
- The room temperature and humidity sensors.
- The water temperature sensors for each heat exchanger.
- All air and water pressure sensor readouts.
- All flow measuring device readouts.

WHAT INVOLVEMENT SHOULD TAB HAVE TESTING CONTROLS

STANDARD REQUIREMENTS (Cont.)

Point Verification

- Point verification for the digital control system documents that every point is operational and the setpoint, flow, temperature, or pressure is reporting correctly to the graphic interface. Verify and document all points.

Dynamic Testing

- Dynamic testing involves making a change of value at the sensor in order to observe the systemôs reaction and how it regains the original setpoint. Verify and document the systemôs response.

Please reference the *AABC National Standards for Total System Balance* for which an update will be published in 2015.

Testing Terminal Unit Control Boxes

Requirements of the Testing and Balancing Firm

Terminal Unit and Packaged Airflow Controllers

1. The TAB firm should verify the calibration of all airflow sensors and control devices for ventilation and zone airflow control.
2. The TAB firm should document in the final TAB report the non-default operating parameters of packaged terminal controllers (i.e. setpoints, flow coefficients, inlet size parameters, etc.)
3. The TAB firm should perform basic functionality testing of terminal controls (damper, valve, heat strip, fan operation, etc.)
4. The TAB firm should verify and document the calibration of all zone temperature sensors (i.e.. thermostats, discharge air sensors, etc.)

Terminal Unit Control Configuration and Sequence Verification Data

TERMINAL UNIT NUMBER	1			
EQUIPMENT TAG	VAV-1-1			
CONTROL SYSTEM NAME	ABC-1-1			
THERMOSTAT (LOCATION / COMMUNICATION)	OK			
SUPPLY AIR ZERO FLOW	OK			
SUPPLY AIR DAMPER OPERATION (OPEN / CLOSE)	OK			
HOT WATER VALVE OPERATION (OPEN / CLOSE)	OK			
CONTROL SEQUENCE TYPE (SEE SEQUENCE SUMMARY)	A			
CONTROL SEQUENCE VERIFICATION	OK			
TEC ADDRESS (01)	1			
TEC APPLICATION (02)	XYZ			
CLG MIN (31)	250			
CLG MAX (32)	500			
HTG MIN (33)	250			
HTG MAX (34)	500			
FLO COEF (36)	0.65			
MTR 1 TIMING (51)	90			
MTR 2 TIMING (55)	130			
MTR SETUP (58)	5			
SWITCH TIME (86)	2			
DUCT AREA (97)	0.35			
DATE TESTED	2/2/2015			

WHAT INVOLVEMENT SHOULD TAB HAVE TESTING CONTROLS

TAB Assistance with Control System Tuning

1. The TAB Firm should determine maximum **AND** minimum static or differential pressure setpoints for **ALL** Variable Volume Systems.
2. Determine as part of total system capacity testing
3. Should take into account design capacity of equipment vs. connected load (i.e.. diversity)
4. Setpoints should be determined for all modes of operation (i.e.. occupied / unoccupied with resets, variable air change rates in lab and animal spaces, etc.)
5. These setpoints and the methodology for determining each should be included in the final TAB Report for future use by the Operations staff.
6. The TAB firm should determine appropriate offsets / pressure control setpoints for pressure dependent spaces (i.e.. operating rooms, isolation rooms, laboratories, clean rooms, etc.) based upon actual operating conditions and construction.

Testing Air Handling Units

AIRFLOW PROFILE COOLING

BOX NUMBER	VALVE NUMBER	DESIGN MAXIMUM CFM	ACTUAL MAXIMUM CFM	ACTUAL DISPLAY MAXIMUM CFM	ACTUAL MAXIMUM DAMPER POSITION %
1	TB-01-01	2180	2185	2180	57.0
2	TB-01-02	2030	2070	2030	66.0
3	TB-01-03	2720	2730	2720	56.0
4	TB-01-04	2720	0	0	0.0
5	TB-01-05	2720	0	0	0.0
6	TB-01-06	2720	2720	2720	90.0
7	TB-01-07	1250	1250	1250	68.0
8	TB-01-08	1050	1030	1050	40.0
9	TB-01-09	1400	1400	1400	50.0
10	TB-01-10	1560	1560	1560	60.0
11	TB-01-11	1675	1645	1675	62.0
		22025	16590	16585	

Box(s) not in control at time of test:	None	VFD Hertz:	60	Final Cooling Static Pressure Setpoint:	2.910ò w.c.
Diversity, if applicable: Box #	4, 5	=5440	CFM Closed for diversity	Final Heating Static Pressure Setpoint:	2.910ò w.c.

Testing Air Handling Units

AIRFLOW PROFILE HEATING

EAB BOX NUMBER	VALVE NUMBER	DESIGN MAXIMUM CFM	ACTUAL MAXIMUM CFM	ACTUAL DISPLAY MAXIMUM CFM	ACTUAL MAXIMUM DAMPER POSITION %
1	TB-01-01	1640	0	0	0.0
2	TB-01-02	1510	1520	1510	66.0
3	TB-01-03	2040	2025	2040	60.0
4	TB-01-04	2040	2040	2040	97.0
5	TB-01-05	2040	2050	2040	65.0
6	TB-01-06	2040	2040	2040	65.0
7	TB-01-07	940	940	940	77.0
8	TB-01-08	840	0	0	0.0
9	TB-01-09	1050	0	0	0.0
10	TB-01-10	1240	1245	1240	79.0
11	TB-01-11	1260	1250	1260	69.0
		16640	13110	13110	

Box(s) not in control at time of test:	1,8,9		VFD Hertz:	53	Final Cooling Static Pressure Setpoint:	2.910" w.c.		
Diversity, if applicable: Box #	1,8,9	=	3530	CFM Closed for diversity	Final Heating Static Pressure Setpoint:	2.910" w.c.		

WHAT INVOLVEMENT SHOULD TAB HAVE TESTING CONTROLS

Programmable I/O Controllers and Sensors

1. The TAB firm should verify the calibration of all temperature and pressure sensors and document testing results in the final TAB report
2. Offsets or calibration factors from default values should be recorded
3. Measured values should be recorded in close proximity to the sensor being measured and simultaneously with displayed values when possible
4. The TAB firm should verify and document correct operation and point termination of all control dampers, control valves, digital outputs and digital inputs
5. The TAB firm should test all mechanical safeties interlocked to the control system and determine proper safety setpoints that may not be clearly denoted in the project documents (i.e.. high and low static pressure switches)

Sensor Calibration and Control Point Verification Form

UNIT NUMBER	DDC POINT	POINT TO POINT	DDC VALUE	ACTUAL VALUE	DATE	REMARKS
VAV-1-1	ABC-1-1:Room Temperature	OK	72.0° F	71.8° F	2-2-15	
VAV-1-1	ABC-1-1:Room Temperature Setpoint	OK	72.0° F		2-2-15	
VAV-1-1	ABC-1-1:Airflow Setpoint	OK	500/250 CFM		2-2-15	
VAV-1-1	ABC-1-1:Airflow	OK	500/250 CFM		2-2-15	See Air Distribution Data
VAV-1-1	ABC-1-1:Airflow Damper Position	OK	0-100%		2-2-15	
VAV-1-1	ABC-1-1:Hot Water Reheat Coil Control Valve Position	OK	0-100%		2-2-15	
VAV-1-1	ABC-1-1: Terminal Unit Discharge Air Temperature	OK	54.0° F	54.2° F	2-2-15	
VAV-1-1	ABC-1-1: Terminal Unit Discharge Air Temperature	OK	94.0° F	94.2° F	2-2-15	

The Commissioning Process for HVAC Systems

Acceptance Phase ï Functional Performance Testing

Functional Performance Testing should achieve the following:

1. Verify all elements of the sequence of operations indicated in the project documents is functional as installed
2. Verify appropriate interlocks and tuning have been performed to ensure stable operation and control of temperatures and pressures within the facility
3. Verify proper alarming setup within the Control System
4. Document the operation of the SYSTEM across the entire operating range (maximum to minimum)
5. Any issues or non-standard conditions should be noted in the Commissioning Issues Log (CxIL) for record.
6. The CxA should write test procedures, facilitate and document testing with assistance from the TAB Firm, Contractor, Controls Vendor and Ownerôs O&M personnel.

The Commissioning Process for HVAC Systems

Acceptance Phase ï Functional Performance Testing

Be specific with descriptions of initiating steps in test procedures:

1. Fail the fan by placing the Hand-Off-Auto switch to the Off position on the motor starter.
2. If someone not involved with the testing of the system read the completed verification procedure, can they tell how the system was tested?
3. Challenge PID control loops and observe performance at both steady state conditions as well as dynamic conditions (i.e.. startup, emergency modes, etc.)
4. Verify all Automatic AND Local control scenarios

The Commissioning Process for HVAC Systems

Acceptance Phase ï Functional Performance Testing

Variable Volume Control Verification:

1. Systematically operate terminal units / valves within a variable volume system individually or in groups across the entire operating range from maximum to minimum
2. Verify static pressure and differential pressure reset ranges (TAB data should be reviewed and verified by the CxA during this step.)
3. Report operating data for the system at minimum control conditions (this indicates energy savings to the Owner)
4. Verify Lead / Lag staging of equipment

The Commissioning Process for HVAC Systems

Acceptance Phase ï Functional Performance Testing

Fire Alarm / Smoke Control Sequences

1. Initiate sequences in coordination with fire alarm testing
2. Verify equipment failure scenarios
3. Verify critical equipment transfer to backup power systems
4. Verify Firemanôs Override and local controls in addition to automatic control sequences for HVAC equipment
5. Duct Mounted Smoke Detector differential pressures at minimum airflows should be verified by either the TAB personnel or the Fire Alarm contractor in accordance with the manufacturerôs recommendations.

The Commissioning Process for HVAC Systems

Occupancy Phase ï Owner Training

The Ownerôs O&M personnel should be trained to operate the HVAC and control systems based upon the design requirements

1. Qualified Instructors (not sales personnel) should conduct training sessions.
2. Training should include classroom sessions related to O&M manuals and field sessions for hands-on training.
3. Sessions should be video taped in a high quality manner for use by the Owner for on-going training needs.
4. The CxA should review the quality of the sessions against the requirements in the project specifications
5. The design team and TAB firm should conduct training sessions to give BOD and system performance perspectives and answer questions from the O&M staff.

The Commissioning Process for HVAC Systems

Occupancy Phase ï Measurement and Verification

The following should be conducted by the CxA, EMP, or Owner within the first year of occupancy and regular intervals thereafter as required:

1. Evaluate Occupancy Schedules vs. Equipment Schedules
2. Conduct Occupancy Surveys to gauge comfort levels and get feedback for improvement
3. Conduct O&M surveys to determine issues and proficiency of training
4. Compare energy usage to design energy model using established M&V techniques
5. Fine tune the control system for optimization during all seasons of operation and occupancy patterns.

The Commissioning Process for HVAC Systems

Consequences of not verifying control systems through Test, Adjust and Balance **AND** Commissioning:

1. Up to 50% failure rates of control point terminations
2. Sequences of Operation that do not meet the design intent
3. Sensors setup for incorrect ranges and setpoints
4. Energy conservation measures abandoned due to faulty control installation and occupant discomfort
5. Wasted energy from systems operating outside of design parameters due to control calibration errors
6. Equipment failures from excessive cycling due to lack of tuning

All of these can happen in a **BALANCED** building **but not with TOTAL SYSTEM BALANCING**!

Control Verification is a team effort!

QUESTIONS?

ENGINEERED AIR BALANCE

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