AABC Commissioning Group
AIA Provider Number 50111116

Controls Verification + Test & Balance = A Smoother Commissioning Process

Course Number: CXENERGY1730

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Course Description

When properly specified, Total System Balance of HVAC systems includes verification of controls. Focusing on terminal units and AHUs as examples, this session presented by AABC will explore how complete verification of control configurations and sequences by the test and balance agency can save significant commissioning time.

Learning Objectives

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

1. Understand the recommended roles of the Test, Adjust and Balance (TAB) Firm in verifying control sequences for basic variable volume air handling systems in coordination with a standard commissioning process.

2. Understand the data that should be provided by the TAB Firm to the Commissioning Team, and specifically the Cx Authority, prior to the start of HVAC Functional Performance Testing.

3. Understand the process utilized by the TAB Firm to determine appropriate pressure setpoints for variable volume systems across the entire system operating range and how this data should be utilized and verified by the Cx Authority.

4. Understand how the Cx Authority should and should not utilize the TAB firm in support of HVAC Functional Performance Testing to provide the best value to the Owner.

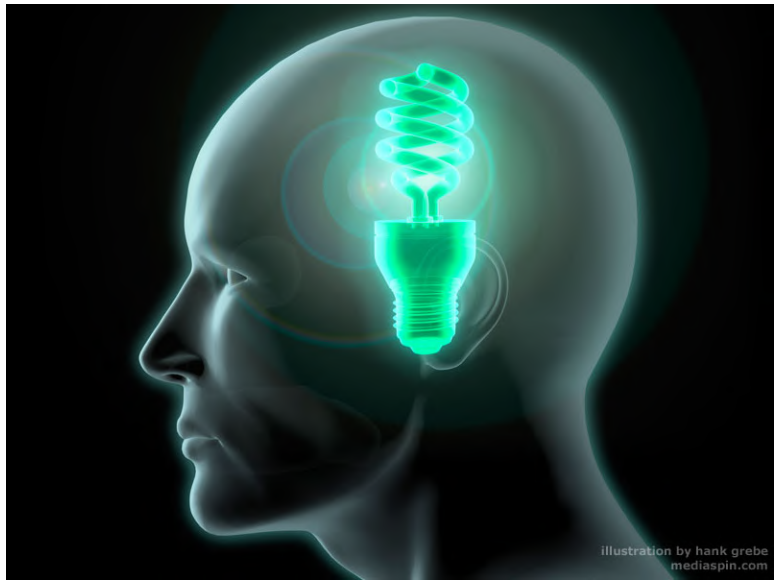
Control Verification + TAB = Smooth Commissioning

How should the TAB Firm and Commissioning Authority (CxA) work together to verify the HVAC systems?

What is the best VALUE for the Owner?

Who is most qualified for the various tasks involved in commissioning of HVAC systems?

What is the end goal……



OWNER SATISFACTION

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COORDINATION IS ESSENTIAL FOR SUCCESS

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TAB FIRM RESPONSIBILITIES

1. Balanceability Review
2. Pre-Balance Observations
3. Proportion **Air / Water Distribution**
4. Measure **Equipment Performance**
5. Control Point and **Sensor Calibration** Verification
6. HVAC **Control Verification**
7. Cx Process **Support**

CX AUTHORITY RESPONSIBILITIES

1. Coordinate and **Lead** the Cx Process
2. Perform reviews to confirm **OPR compliance**
3. Document procurement and installation using **System Verification** Checklists
4. Develop **Functional Performance** Testing Procedures
5. Facilitate and document **Functional Performance** Testing

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AABC / ANSI ***NATIONAL STANDARDS FOR TOTAL SYSTEM BALANCE*** REQUIREMENTS

- 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 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.

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AABC / ANSI ***NATIONAL STANDARDS FOR TOTAL SYSTEM BALANCE*** REQUIREMENTS (CONTD.)

- Verify that all controlled devices are properly installed in the distribution system in relation to direction of flow and location.
- 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.
- Determine that all controlled devices are properly connected.
- Confirm that all controlled devices are operated by the intended controller.

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AABC / ANSI ***NATIONAL STANDARDS FOR TOTAL SYSTEM BALANCE*** REQUIREMENTS (CONTD.)

- 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%.
- Verify controller setpoints meet the specification.
- Confirm the sequences of operation for all control modes are in compliance with the final approved control submittal.

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AABC / ANSI ***NATIONAL STANDARDS FOR TOTAL SYSTEM BALANCE*** REQUIREMENTS (CONTD.)

- 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.

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AABC / ANSI ***NATIONAL STANDARDS FOR TOTAL SYSTEM BALANCE*** REQUIREMENTS (CONTD.)

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.

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AABC / ANSI ***NATIONAL STANDARDS FOR TOTAL SYSTEM BALANCE*** REQUIREMENTS (CONTD.)

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.

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AABC / ANSI ***NATIONAL STANDARDS FOR TOTAL SYSTEM BALANCE*** REQUIREMENTS (CONTD.)

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 system's reaction and how it regains the original setpoint. Verify and document the system's response.

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WHAT SHOULD THE CxA ASK:

WHAT DOES THE **TAB SPECIFICATION** REQUIRE FOR CONTROL VERIFICATION?

IS CONTROL VERIFICATION INCLUDED IN THE **TAB SCOPE** FOR THE PROJECT?

IS THE TAB AGENCY **QUALIFIED** TO PERFORM CONTROL VERIFICATION IN SUPPORT OF THE CX PROCESS?

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Construction Phase Controls Coordination

1. Can software be loaded onto the TAB Technician's or CxA's laptop or will the control vendor furnish a licensed laptop?

2. Is a "Balancing Tool" 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?

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Construction Phase Controls Coordination (contd.)

6. Does the TAB Technician or CxA have access to an Operator's Workstation or "Graphical Interface"

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 PERFORMANCE TESTING BEGIN!

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Testing and Balancing – Terminal Unit Controls

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			

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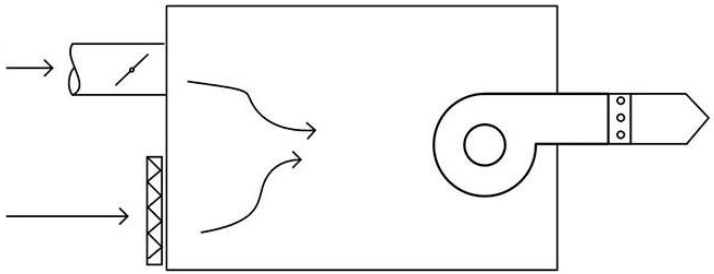
Testing and Balancing – Series Fan Powered Terminal Unit

1. With primary airflow within 80% of maximum, proportion supply outlets and adjust fan speed to controller to achieve design fan airflow

2. Utilize the appropriate device on the return inlet to verify neutral airflow conditions and adjust the primary airflow sensor to achieve a neutral return condition

3. Measure supply airflow and perform final calibration on primary airflow sensor; perform cold slug verification of hydronic heating water coil

4. Command primary airflow to minimum; verify minimum airflow utilizing test ports; verify heating coil / element operation and capacity at design mixed plenum temperature.



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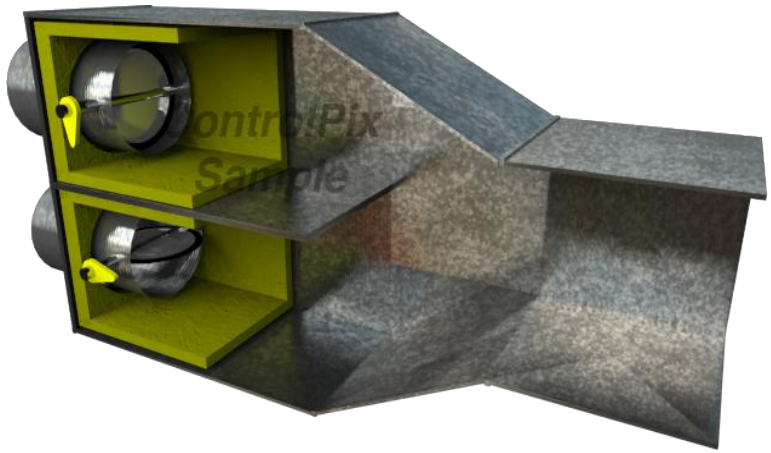
Testing and Balancing – Dual Duct Terminal Unit

1. Close hot deck damper and command cold deck to design airflow; proportion outlets and calibrate cold deck airflow sensor

2. Close cold deck damper and command hot deck to design airflow; measure airflow and calibrate hot deck sensor

3. Release cold deck damper and command to minimum mixed airflow; verify crossover point and minimum cold deck airflow as required



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Variable Volume System Testing (during System Capacity Testing)

1. The TAB Firm should determine maximum **AND** minimum static or differential pressure setpoints for **ALL** Variable Volume Systems.

2. Analyze design capacity of equipment vs. connected load (i.e.. diversity)

3. 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.)

Testing Air Handling Units

AIRFLOW PROFILE COOLING (16,500 CFM Coil)

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 :		None	VFD Hertz:	59.8	Final Cooling Static Pressure Setpoint:	1.9”	w.c.
Diversity, if applicable: Box #	4, 5	-5440	CFM		Final Heating Static Pressure Setpoint:	1.3”	w.c.

Testing Air Handling Units

AIRFLOW PROFILE HEATING (13,000 CFM Coil)

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:	NONE		VFD Hertz:	52.6	Final Cooling Static Pressure Setpoint:	1.9	" w.c.
Diversity, if applicable: Box #	1,8,9	= 3530 CFM			Final Heating Static Pressure Setpoint:	1.3	" w.c.

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Air Handling Unit Control Verification – TAB Responsibilities

1. 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

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	

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Air Handling Unit Control Verification – TAB Responsibilities (contd.)

5. Test all mechanical safeties and determine proper setpoints that may not be clearly denoted in the project documents (i.e.. high and low static pressure switches)

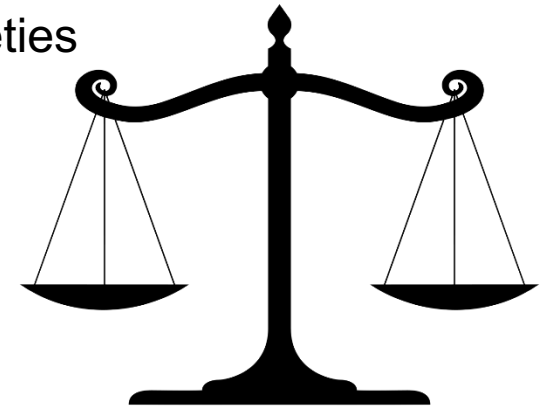
6. Verify system interlocks and basic sequence functionality prior to Functional Performance Testing by the CxA

CORRECT TAB CONTROL VERIFICATION = SMOOTH FUNCTIONAL PERFORMANCE TESTING + MINIMAL SCOPE DUPLICATION

The Commissioning Process for HVAC Systems

HVAC Functional Performance Testing – TAB

1. Measure flows, pressures, electrical data, and temperatures as required to verify performance during the FPT
2. Demonstrate appropriate calibration of sensors and safeties as required
3. Utilize prior measurement data where appropriate
4. Provide VAV System Profiles for reference during FPT
5. Provide terminal unit setup and testing data for review by CxA
6. Provide AHU performance data for review by CxA



The Commissioning Process for HVAC Systems

HVAC Functional Performance Testing - CxA

1. Verify all elements of the sequence of operations indicated in the project documents are 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.

The Commissioning Process for HVAC Systems

WHAT NOT TO DO:

1. Functional Performance Testing of individual terminal units
2. Multiple calibration verifications
3. Multiple TAB verifications
4. Multiple BAS Point Verifications
5. Put an FPT cover letter on the TAB Control Verification documents

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!

This concludes The American Institute of Architects Continuing Education Systems Course

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