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WHAT SHOULD THE DESIGN ENGINEER EXPECT THE TESTING, ADJUSTING, AND BALANCING AGENCY TO DO?

G. Richardson
ASHRAE Member

ABSTRACT

This paper discusses guidelines for testing and balancing, lists qualifications for the TAB agency, and gives an overview of TAB work at various stages of construction.

INTRODUCTION

ASHRAE Guideline 1—1989, Guideline for Commissioning of HVAC Systems, states its intentions to formulate procedures for:

"(a) The documentation of occupancy requirements and design assumptions for the HVAC design
(b) The documentation of the design intent for use by contractors, owners, and operators
(c) Functional performance testing and documentation necessary for evaluating the HVAC system for acceptance
(d) Adjusting the HVAC system to meet actual occupancy needs within the capability of the system"

The *National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems*, Fifth Edition, 1989 by the Associated Air Balance Council states the member agencies

1. Provide the Engineer Client with completely reliable documentation of the system and its performance.
2. Provide system information that can be verified by the Engineer or Client.

"Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems, Fifth Edition, 1991, by the National Environmental Balancing Bureau states, "The work must be performed as specified. Every item called for in the specification by description, or by reference, must be performed and recorded in the TAB reports. Data presented in a TAB report shall be accurate and must provide an exact record of system performance information requested by the specifying agent."

Each of the above statements appears to meet the intent of items (c) and (d) in the ASHRAE guideline. Through the years, this concept has been abused by people trying to go through the functions of testing but not being able to analyze and document the total system performance.The ASHRAE guideline recommends that a commissioning agent be established who follows the project from predesign to the occupancy stage. The commissioning agent develops the commissioning plan, observes functional performance tests, establishes the documentation, and verifies all documentation. The commissioning agent can be the design engineer, an outside engineer, the owner's representative, the construction manager, or another. The final sign-off of the system and acceptance is the design engineers's responsibility. The design engineer certifies that the building meets the design criteria.

The TAB agency's responsibility is to establish at some point that all components, subsystems, systems, and interfaces between system functions are in accordance with the contract documents, which is part of the ASHRAE guideline's definition of functional performance testing. The guideline notes, "function includes all modes and sequences to control operation, all interlocks and conditional control responses, and all specified responses to abnormal emergency conditions." This paper will discuss issues in obtaining an adequate functional performance test.

QUALIFICATIONS

To perform the functional performance test mentioned above, the TAB agency must have qualified personnel to establish the testing procedures and the documentation required. Therefore, the agency should develop a "qualifications resume," which will include, as a minimum, the following:

1. Résumés of all personnel who will be involved in the project's work, which will establish the following:
   A. Educational background, including special training and certification

Gaylon Richardson is a vice-president with Engineered Air Balance Co., Inc., Houston, Texas.

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Author :Cohen:T.

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Argues time has come for HVAC industry professionals to develop the methods and procedures to provide for positive ventilation requirements to be established, controlled, and tested for acceptance and certification. These tests will include the design professional, the HVAC contractors, the automatic controls contractor, and the Testing and Balancing (TAB) agency. Addresses the steps involved in the design, construction, and testing of an HVAC system to ensure the delivery of satisfactory IAQ in a facility. The primary emphasis is on four important factors that affect the development of an HVAC system. These guidelines apply to the design of a new HVAC system or the modification of an existing facility - 1) The design professional must include the controls system and the means of proportioning the return air and outdoor air intake (OAI) airflow rates in the design process. 2) The contractor responsible for conducting the acceptance tests should be retained during the design phase of the project so that he or she may provide expertise with regard to the automatic controls and the balance of the airflow and water-flow systems. 3) The interface and cooperation between the automatic controls contractor, the TAB contractor, and the contractor for the acceptance tests should be more comprehensive than current common practice. 4) The contract for the acceptance tests should be made directly with the owner.

B. Experience level and classification
   1. Field technician
   2. Project supervisor
   3. Project manager
   4. Project coordinator
   5. Project administrator
C. Principals of the firm
D. Participation in organizations (including certification)

2. Project references (provide at least six)
   A. List of similar projects with owner, architect, and engineer contacts
   B. List of present projects with size description
   C. List of past projects with size description
3. Instrumentation
   A. Generic list of instrumentation available that will be applied to the project (A detailed list indicating calibration dates and serial numbers of instruments used should be included in the final report.)
   B. Quality control program
      1. Calibration procedure
      2. Instrument control
4. Documentation form samples
5. Sample of procedural outlines consistent with the project being considered

HIRING A TAB FIRM

In the conceptual stage of the project, the TAB agencies should submit their qualification résumés and proposals. The conceptual drawings should be in the final stages, showing system layout and intent. The TAB firm's proposal should include the following:

1. Cost for document review for balanceability prior to bid documents being issued
2. Cost of establishing functional performance procedures and documentation procedures that are acceptable to the design team (These procedures should identify individual systems and methods of testing, if variable volume, through a full range of air or water flow.)
3. Cost for construction observations
   A. Special testing (i.e., mockups of systems, trips to manufacturing plants to witness equipment tests, etc.)
   B. Submittal review by verifying that the equipment meets the specification and schedule plus review for balanceability
   C. Cost for construction observation, which as a minimum will include the following:
      1. Piping
         a. Coil piped counterflow
         b. Control and balancing valves installed in correct location and direction
         c. Pressure taps installed in correct location
         d. Flowmeter installed in correct location
         e. Air vents located at all high points
         f. Thermometer wells located in proper locations
         g. All strainers, air separators, heat exchangers, expansion tanks, pumps, etc., installed in the proper location
      2. Ductwork
         a. Observe that duct gauges and fittings meet the specifications
         b. Observe method of sealing
         c. Observe if all dampers are installed in the correct location
         d. Observe that tap locations are installed in the proper location, both upstream and downstream of terminal boxes
         e. Observe that ductwork has not been modified in a manner that will increase resistance or create system effect losses
      3. Observe return air paths to make sure return air openings above the ceiling are installed as specified in the design documents and not restricted by ductwork, cable trays, pipes, etc.
      4. Observe exterior construction of perimeter walls to eliminate improper infiltration or infiltration by looking for light or air passing
   D. Duct pressure testing and/or witnessing
4. Cost of testing, adjusting, and balancing
5. Cost of special testing
   A. Chiller capacity test
   B. Boiler efficiency test
   C. Cooling tower capacity testing
   D. Point verification of DDC system
   E. Smoke control systems
      1. Smoke removal
      2. Stair pressurization
   F. Sound testing
   G. Vibration testing
6. Cost of occupancy reverification
7. Cost of opposite season testing
8. Cost of training the maintenance personnel
9. Hourly rates for retesting of systems if they were not complete or some extenuating circumstance would not allow the system to be finalized

Each of these items can be modified to fit the actual job conditions. There could be other costs, such as mobilization, existing building system capacity tests, etc., but the main idea is the TAB agency will be part of the consultant team and, once hired, special testing can be considered when warranted by the team.

DESIGN PHASE

During the design phase, the TBE (testing and balancing engineer) should interface with the design team, identifying practical experiences with various types of systems. Prior to the bid documents being released, the TBE will become familiar with the mechanical plans and specifications and note any items that will assist the project in the functional testing stage. The TBE will prepare a functional test outline for the project by describing the system and how it will be tested and documented.

The final item in the design stage is to attend the pre-bid meeting. In this meeting, the following will be established:

1. The TAB agency's role in the project
2. That TAB agency will be included in the submittal process and will send all comments to the design engineer
3. The time that will be required to test the systems at the end of the project and any special testing concerns or coordination concerns
4. The contractor coordination specification with the TAB agency
5. How duct pressure testing will be accomplished
6. A pre-submitted review of the control contractor's interpretation of the control specification and how the intent will be met.

CONSTRUCTION PHASE

During the construction phase, the TAB agency will be involved in the following:

1. Mock-up equipment testing prior to submittal acceptance as identified by the specifications.
2. Scheduling
   A. Control contractor pre-submittal meeting
   B. Duct pressure testing
   C. Functional performance testing
      (*Note*: It must be established that functional testing has to be done on complete systems and the completed schedule needs to be generated for testing, which may not be on a per-floor basis.)
   D. Schedule of special tests
   E. Schedule of control function testing
   F. Schedule of occupancy testing
   G. Schedule of opposite season testing
3. Submittal review
4. Observation reports on the piping, ductwork, return-air paths, and building envelope
5. Duct pressure testing

FUNCTIONAL PERFORMANCE PHASE

After the contractor has performed the equipment start-up, which should not be done on a single piece of equipment but on a complete system, the contractor will notify the owner and the TAB agency that the systems are ready for functional performance testing. The TAB agency should follow the procedures established in the design stage and document the findings on approved data sheets. As stated in the ASHRAE Guideline, paragraph 8.3.2., "The functional performance testing process should be accomplished for all equipment, subsystems, systems, and system interface. There may be several similar pieces of equipment, systems, etc., on a project. All must be tested for acceptances, and there should be a separate checklist for each to ensure documentation specific to each is complete. The checklist could be the documentation form that was developed in the design phase."

It should be noted that each control component is included in the checklist mentioned above. Each control component should be observed to determine its spring range, setpoint, span, high and low limits, calibration, etc. This checklist would include verifying the I/O summary in the DDC system.

If, acceptable performance cannot be achieved in the functional performance testing because of system or construction deficiency, the necessary data will be given to the contractor for correction. After the correction is made, the contractor will notify the owner and TAB agency so that the system can be retested. If the deficiency in the system requires modification, the design team will be notified and they will issue the appropriate directions.

During the functional performance testing, the operations and maintenance personnel should be trained by the following methods as they relate to the testing performed by the TAB agency:

1. Observe air-side testing, to understand the type of systems, how the systems are controlled, and the various modes of operation.
2. Observe the hydronic testing to understand the type of systems, how the systems are controlled, and the various modes of operation.
3. Troubleshooting techniques should be established and the maintenance personnel trained how to methodically verify a complaint and report it during the occupancy stage of the project.

After the functional performance testing is completed, a report should be submitted to the design engineer for review and approval. The engineer's approval of the functional performance testing certifies to the owner that the HVAC system is completed. It should be noted that certain parts of the systems may need to be tested during opposite season or at full occupancy, etc. Any deferred testing should be reported in a supplemental report.

Functional performance testing reports should contain the following:

1. Cover sheet identifying:
   A. The project and location
   B. The commissioning team, company names, and contact person with phone number
   C. The design team with contact person and

phone numbers
   D. The contractors with contact person and phone number
2. System description
   A. Special conditions of operation, i.e., diversity and how it was established
   B. The basic components
   C. How the system is controlled, noting any change from the specifications
3. System documentation
4. Pertinent submittal
5. Drawing identifying system components

The above items can be enhanced by adding specific requirements of the report in the specification as described in Chapter 13 of *ANSI/ASHRAE 111-1988, Standard Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air Conditioning, and Refrigeration Systems.*

OCCUPANCY STAGE

During the occupancy stage, the space temperatures should be recorded to observe if the system operates within the design tolerances. The TAB agency should address the maintenance personnel's complaint log and verify that the problem was resolved and done correctly. If any adjustments are required, these should be documented on the appropriate documentation forms and submitted as revisions. If the systems cannot maintain comfort level, pressure, temperature, etc., due to occupancy being different from the design, the data should be given to the design professional who will review and issue whatever directions are necessary (if an energy management system is available, by trending temperatures for two to three days or by using recorders in each zone of a day).

The scope of this paper is generic and should be modified to fit each project. The TAB agency's role in the scope of this document is identifying deficiencies, documenting system operation and capacities, and giving a final report stating at some point that all systems have performed in a manner that meets the design intent.

The design intent can easily be misunderstood if there is not communication between the designer and the TAB agency. For example, an engineer had designed a dual-duct system for a total airflow of 25,000 cfm and 19,000 cfm through the cold deck with an external resistance of 1.6 in. w.c. The terminal boxes had an upstream control for the cold deck and a downstream make-up controller for the neutral duct. The base building balancing report indicated the cold deck could produce slightly over 19,000 cfm through the cold deck at design cfm. During the tenant buildout balancing, it was found that only 12,000 cfm could be obtained through the cold deck. There was insufficient static pressure to obtain design cold airflow at each terminal that was set to full cooling. After reviewing the static pressures, the problem was identified; the 2 in. filters had 1.0 in. w.c. pressure drop and were clean. The filter rack was a low-velocity design, and a high-velocity design was required. After installing a high-velocity filter rack, the terminal units on full cooling closed the neutral duct and the cold deck design was 19,000 cfm. The initial TAB agency stated that they closed off the neutral ducts to get design airflow of 19,000 cfm. The closing of the neutral duct was not mentioned in their report.

The above is a simple example of capacity testing versus functional performance testing. If the specification stated, *"Set the system for diversity by putting terminals to full cooling at the remote points of the system to total the cooling coil requirement and the remaining terminals to full heat. Verify the discharge air temperature is within 1° of the inlet on all boxes set for cooling and traverse for total airflow in the hot and cold deck,"* then the problem could have been found at the initial balance.

In conclusion, the functional testing should be considered in steps to produce a report that defines the system operation and indicates its capacity. The design engineer must be specific in the specification as to the scope of testing and reporting and needs to witness or have confidence that the tests are providing the correct results.

REFERENCES

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DISCUSSION

Vin Gupta, Supervisor, 3M, St. Paul, MN: Should the testing and balancing be done by an independent contractor? Should equal emphasis be placed on air and water systems?

G. Richardson: Yes, TAB should be done by an independent TAB agency. A total system is composed of air systems, water systems, and control systems, all of which have to be tested to make a complete system.

Ernest E. Choat, Owner, Environmental Engineering Consultants, Oak Ridge, TN: To ensure satisfactory completion of TAB work, it is not sufficient for engineers to simply specify that the work shall be done by an NEBB- or AABC-certified firm, as was indicated in NO-94-4-1 and NO-94-4-3. Nor is it sufficient to simply specify that work shall be done in accordance with the standards that were cited in NO-94-4-1, as these are woefully inadequate.

In my view, the design engineer must specify and approve the qualifications of individuals of the TAB team that is to do his or her work to ensure that a qualified team is supplied. The author discussed this briefly in the first part of this presentation but failed to emphasize it to the extent that it deserves.

Richardson: Many systems are complex and require the experience of skilled technicians and engineers. Each project will require a high level of skills which should be established in the TAB agency's proposals.