

TESTING AND BALANCING FOR THE 1990s

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ABSTRACT

Until the late 1950s, virtually no firms specialized exclusively in testing, adjusting, and balancing the components of heating, ventilating, and air-conditioning (HVAC) systems. The balancing, if performed at all, was done by the HVAC contractor, who lacked the necessary expertise required for advanced testing and balancing. After installation, many design engineers found that their systems were not working, not because of flawed design but because of improper balancing or deficient performance of the equipment. As a result, independent rating associations were founded by reputable members of the industry to standardize fan testing methods and develop better field testing procedures. The need for independent testing and balancing companies also became apparent.

INTRODUCTION

In 1965 a small group of independent test and balance engineers founded the Associated Air Balance Council (AABC); in 1976 the National Environmental Balancing Bureau (NEBB) was founded; and in 1989 ASHRAE approved Standard 111 for testing and balancing. AABC wrote the first industry standards for testing and balancing. The standards specified that member agencies provide the engineer or client with completely reliable documentation of the system and its performance—system information that could be verified by the engineer or client.

The AABC promoted the concept of total system balance, which is the process of testing, adjusting, and balancing environmental and other systems to produce the design objectives.

Testing and balancing (TAB) in the HVAC industry is a fascinating challenge. It is a scientific practice, not a defined science; therefore, the opportunity arises for miscalculations and, in some cases, misrepresentation. There are many areas of expertise, and it takes years to learn the impact of each discipline involved in modern HVAC systems. Each air treatment process in the system contributes a specific function to produce proper environmental conditions. However, it is the coordinated action of all these processes—each related to and influencing the others—that produces the desired conditions. If any one of

these coordinated functions does not perform as designed, the final system performance will be reduced.

The purpose of the test and balance agency is to test the capacity of the fans, pumps, and the heat transfer equipment as they actually operate in the field and to balance all flow rates to the design values. Total system balance is the process of testing and balancing each system component so that the entire system produces the results for which it was designed. It is a science that requires the proper use of instruments, verification of instrument calibration, intelligent evaluation of readings, and adjustment of the system to design conditions. Having an HVAC system that works properly is too important to leave to chance.

EARLY DAYS

In the early days, the main work required of a test and balance engineer involved measuring the airflow to an air device and adjusting a manual balancing damper until the specified flow rate was obtained. This procedure was repeated for all air devices in the building until the airflow to each area was balanced in the proper proportion to the other areas. A similar method was used to balance water.

One of the most important functions performed by a test and balance agency, then and now, is to bring to light the problems and discrepancies that exist in every construction project. The simple procedure of going to each piece of equipment and testing it for correct operation inevitably turns up problems that, when corrected by the responsible party, ensures that the owner does not have to deal with those problems after occupancy.

The first tools of the trade included pitot tubes, manometers, air velocity meters, thermometers, tachometers, amp/volt meters, and slide rules. The same instruments, are still used but most of them have the words "electronic digital" in their names. Some modern specialized instruments have been added, such as sound and vibration analyzers, ultrasound flowmeters, capture flow hoods, and portable computers. However, the pitot tube and manometer are still the main instruments used for determining air velocity.

TODAY'S TESTING AND BALANCING

Testing and balancing is a scientific practice and not a defined science, but there are standards (ASHRAE Standard

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111 and AABC and NEBB standards) to guide one through this process. With these standards, the process of testing and balancing is clearly defined, and the forms to be used, the instrumentation, the requirements to accomplish the job, and, in some cases, the qualifications of the technician and the supervisor are all specified. But these standards do not state who is responsible for the work—the mechanical contractor, the general contractor, the engineer, or the owner—and the question of who has responsibility underlies the majority of all testing and balancing problems that occur.

In most cases, the person who is asked to accept the responsibility for testing and balancing work is the mechanical contractor. At one time, this was the appropriate way for the flow of a project to function. But because the test and balance part of a project is never seen by the occupant or tenant, it has become the one item in a budget that is always substantially reduced. If the mechanical contractor is asked to be responsible and if he or she accepts the responsibility, he or she may be expected to reduce the price to the general contractor. Often, the test and balance portion of the project takes a back seat to the other work, and the owner and/or engineer in many cases will have a system that is inoperable or malfunctioning.

When the specifications are being developed, the owner should accept responsibility for procurement and administration of the test and balance portion of the contract. Then the owner and the engineer can be somewhat assured that if there are flaws and/or systems that are not operating as designed, they will be advised of it properly and in a timely manner so that the necessary corrective action can be taken. The owner should specify that the design engineer is responsible for ensuring the proper results of air and water flow at both full and partial loads and for reviewing the results of the TAB report.

WHY THE OWNER?

Why should the owner hire a testing and balancing firm directly instead of through a mechanical contractor? The simple answer is that a direct-to-owner contractual arrangement has important benefits and advantages:

- The TAB firm has the flexibility to be neutral in areas of conflict. Generally the TAB firm is reluctant to point out problem areas if hired by the mechanical contractor.
- The owner can, during progressive stages of TAB work, discuss various issues with the TAB firm and gain insight into the operational characteristics of the HVAC system, etc.
- The owner obtains
 - direct control of quality assurance services,
 - long-term savings in operating costs,
 - objective TAB services,
 - reduced energy consumption,

- reduced HVAC-related demands on owner's staff time, and
- more comprehensive TAB services.

The expected disadvantages if the owner hires these services are

- more complex dispute resolution,
- more effort on the owner's part,
- some instances of higher first cost, and
- the need for a technical person on the owner's staff.

As system complexity and the desire to increase operational efficiency have increased, the need for testing and balancing firms and the services they provide has become more of an expectation than a luxury in the overall HVAC design/construction picture. Because of these factors, the role of the TAB firm should be reconsidered by the owner or facilities manager if this method is not currently being used.

The issues of who is responsible for and who should manage the TAB services are not new. However, the issues raised have become more important in recent years since it has been acknowledged by facility owners and chief operating engineers that proper TAB is critical to system operations and to obtaining maximum efficiency.

One of the first steps in making TAB a working tool is to determine who will be responsible for procuring and selecting TAB services—the contractor or the owner. The design engineer must specify the TAB requirements and flow station requirements in the specifications. If adequate technical staff is available, it is highly recommended that the owner contract directly with the TAB firm. The owner needs to make the design engineer responsible for the design and the results obtained by the independent TAB contractor.

We suggest that the TAB firm be viewed by the owner as a professional service rather than solely as a contractor and that the selection be based on professional qualifications and performance rather than fee alone. The following minimum TAB firm qualifications should be addressed in the TAB specifications:

- Resumes of those individuals who will be assigned to the project with the cost proposal.
- Representative completed project list.
- National TAB certification verification from the Associated Air Balance Council (AABC), the National Environmental Balancing Bureau (NEBB), or a comparable organization.
- Documentation that the TAB firm has successfully completed projects of this size, complexity, and magnitude.

Although a TAB firm may be certified, the same firm should not install the equipment and then perform the

testing and balancing. It is highly recommended that a professional engineer be under full-time employment for the TAB firm and that this individual review, sign, and stamp the final TAB report. In many cases, the principals of a TAB firm are registered engineers.

Usually, this requirement alone tends to remove an unqualified TAB firm from consideration. It is essential in the case of a complicated HVAC system or clean room. In some areas, a TAB firm may, by state law, be legally considered a professional (similar to an engineer or architect), thereby requiring the owner to review the qualifications of candidate firms and select one based on these qualifications instead of fee alone. A call to the state Board of Engineering Registration should clear up any questions in this area.

SELECTION PROCESS

The selection process varies, however. For a TAB firm to respond properly to a request for proposals, a TAB specification must be prepared. The specification should, at a minimum, address the following:

- overall scope of the project;
- project description and location;
- minimum qualifications of the TAB firm;
- insurance, performance bond requirements, etc.;
- required test instrumentation and calibration certification statement;
- progress walk-through;
- interface with the owner;
- interface with the design engineer;
- interface with the prime construction contractor;
- TAB agenda;
- final report; and
- outline of items to be included in this report.

The mechanical drawings, specifications, approved equipment submittals, and all approved change orders for the project should be included with the TAB specification package. The owner should contact the project architect and/or engineer and obtain these documents.

If an owner chooses to solicit the services of the TAB firm directly, the prime construction contractor should be informed of this in the design specifications prior to bid time. The responsibilities of the TAB contractor should be communicated in the project specification document, which informs the prime contractor and subcontractors that the TAB services will be procured by the owner and advises them about interface with the design engineer and interface between the mechanical contractor and the TAB contractor. Most owners do not have knowledge of testing and balancing and should make the design engineer responsible for obtaining the results.

In most cases, the selection of the TAB firm should be made prior to the actual selection of the project's prime

construction contractor. Experience has shown that the sooner the TAB firm is brought into the project path, the better.

Once the owner has selected the TAB firm, he/she should request that the TAB firm study the project's mechanical documents and present a list of questions and requirements before construction. This allows adequate time to properly address an issue and resolve it through normal channels, usually without construction delays and often avoiding prospective change orders.

The fact is, most qualified TAB firms could walk in on a nearly completed mechanical system and perform adequate testing and balancing. Unfortunately, this is normally the case when the TAB firm is not hired directly by the owner. However, it is advisable on new construction projects that a minimum of three to four walk-throughs be required of the TAB firm prior to starting the actual TAB work in order to achieve the maximum benefits of this work. These can take place at any stage of completion, but experience has shown that these walk-throughs should take place at approximately 25%, 50%, 75%, and 90% completion of the mechanical system. Following a walk-through, the owner and design engineer should request the TAB firm to present a written report of findings, including photographs of recurring problem areas, to add to support documentation. This documentation may be a useful tool to ensure that the prime construction contractor corrects any deficiencies that may be present before a more expensive method has to be employed.

Once actual TAB work begins, it is important to provide the prime construction contractor with an informative listing of field deficiencies. Depending on the situation, it is suggested that the design engineer and owner require the TAB firm to submit daily field reports listing problem areas. These field reports should be given to the design engineer and prime construction contractor. Since TAB work actually begins at 90% to 95% of overall project completion, it is important to provide this information as soon as possible.

Normally, initial TAB field work covers only one mode (i.e., cooling or heating) of HVAC operations. Therefore, the TAB firm should be required to return to the project once seasonal changeover has been made and balance those items not addressed in the initial TAB work. This is particularly important if variable-air-volume systems are employed or if the initial TAB work was performed in the heating mode of operation.

CONCLUSION

Finally, to determine if retaining the TAB firm directly by the owner is appropriate for your next situation, compare this method with previous construction experiences. If you conclude that you gained more insight into the characteristics of the HVAC system and noticed fewer problems with initial HVAC start-up and operation, chances are this method will prove successful for you.

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?

C.N. Lawson: Yes, in my opinion, the testing and balancing must be done by an independent contractor. Yes, equal emphasis should be placed on air and water. In most cases, more emphasis will be placed on the air side due to indoor air quality concerns and the health, welfare, and comfort of the building occupants.

Richard Danks, Chief of Facilities Operations Division, NASA Lewis Research Center, Cleveland, OH: What about doing TAB in-house? Please comment vis-à-vis using a contractor.

Lawson: If an owner has qualified personnel, he or she could accomplish testing and balancing in-house, provided the design work is done in-house. If the contract documents are produced by an independent outside consultant, I feel the testing and balancing should be done by an outside TAB firm. With the outside TAB firm doing the testing and balancing work on the work prepared by an outside consultant, it could eliminate any conflicts that could arise.

Paul Tseng, Chief of Engineering Services, Montgomery County Government, Rockville, MD: Use of an owner-selected TAB contractor raises the question of increasing legal conflict, diluting or muddling liability to the contractor. What effect does this approach have on claim avoidance strategy? Also, if the owner retains his or her own contractor, give the TAB contractor real clout by having him sign off on the monthly draw.

Lawson: In my opinion, there is no legal conflict if the owner selects his or her own testing and balancing firm because it is their building and they want to be guaranteed to a certain degree that the systems are performing as designed. There is again no claim by the mechanical or general contractor if the owner selects his or her testing and balancing firm. I have found that most TAB contractors like this setup even more, for they are not getting beaten to death on price by the mechanical contractor. Having the TAB firm work directly for the mechanical contractor in certain situations is not a healthy position for the owner to be in.

Yes, by having the TAB contractor sign off on the monthly draw does give him some clout; plus, it gives the owner some assurance that his or her systems are being installed per the contract documents. By having the TAB firm responsible to the owner also assures him that certain items are being installed to allow proper testing and balancing.

Mark Hegberg, HVAC Programmer, Commonwealth Edison Co., Oakbrook, IL: Owners and property managers generally are unsophisticated and will not pay for work they do not understand or care about. In my opinion, ASHRAE should mandate responsibilities in a standard for good practice of the industry. In that regard, how can we mandate minimal responsibilities for the TAB firm selection and interaction?

Lawson: I will agree that some owners and property managers are unsophisticated and are not willing to pay for work they may not understand or even care about. It is this type of owner who is constantly having large occupancy turnovers and is paying the high maintenance and energy costs.

ASHRAE is now updating Standard 111, "Testing, Adjusting, and Balancing," and this is the place where responsibilities could be mandated.

I feel we now have minimal responsibilities that have been set forth by ASHRAE, AABC, and NEBB. What is happening is that engineers are too lax in their specifications and, again, in enforcing the specifications. We have engineers who will accept anyone to test and balance their system. Testing and balancing contractors should be selected based on the same type of criteria as a professional engineer, not on price alone.

Ronald Baker, Projects Director, National Institutes of Health, Bethesda, MD: How has your firm evolved from TAB being performed by the mechanical contractor to the owner? Does the design engineer primarily prepare the TAB scope, and have you implemented the task under construction management?

Lawson: Our firm has, for the most part, been an owner's representative, and we have requested that the owner select the TAB firm on professional qualifications, not on price alone.

The design engineer is responsible for preparing the TAB specifications and notifying the various parties that the owner will be responsible for the selection of the testing, adjusting, and balancing firm.

We have discussed the possibility of placing this under the construction manager's responsibility, but you could have the same problems with pricing as if it were under the mechanical contractor's responsibility.

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 this paper. 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 of NO-94-4-2 discussed this view briefly in the first part of his presentation but failed to emphasize it to the extent that it deserves.

Lawson: I agree with you 100% that the design engineer must specify and approve the qualifications of the TAB firm to ensure that the work will be accomplished in a professional manner. As I stated in the paper, resumés of the members of the TAB firm's team should be submitted with the proposal, and selection should be on a professional basis, not price alone.