PERFORMANCE TESTING OF HVAC SYSTEMS FOR AIR QUALITY

Theodore Cohen, P.E.

The concept of performance testing is developing in the heating, ventilating, and air-conditioning (HVAC) industry. The failure of some systems to deliver the services that the owner expects is the primary concern. During construction, the HVAC system is erected and started up, the automatic controls system is set into operation, and the testing and balancing (TAB) of the airflow and water-flow systems is completed. Upon submittal of the TAB report, the HVAC system construction is complete. In the author's experience with HVAC systems, completion of the TAB signifies completion of the contract. There is little or no effort made to verify the performance of the HVAC system, its subsystems, or components. Similarly, there are no acceptance tests to establish that the "as-built" performance of the HVAC system is in accordance with the design intent.

The concept of final acceptance tests came about as a part of the process for commissioning HVAC systems. The tests will commence upon completion of the construction of the HVAC system. This includes the automatic controls and the TAB of the airflow and water-flow distribution systems, as well as verification of the accuracy of the TAB reports and the performance of the automatic controls system.

The final acceptance tests examine the as-built functional performance of each major component and the installed capacity of the heat exchange components. For the air quality procedures, the test will verify the outdoor air and the exhaust ventilation rates. Compliance with the design intent and all applicable codes will enable the indoor air quality (IAQ) procedures to be certified. The final acceptance tests should be witnessed and supervised by the owner's representative or the design engineer.

As building owners and occupants increase demands for air quality in their facilities, federal agencies, code authorities, and the HVAC industry have continued to pursue the most effective means of providing satisfactory air quality conditions. The research efforts of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the U.S. Environmental Protection Agency (EPA), and the National Institute of Standards and Technology (NIST) have determined that maintaining the desired temperature and relative humidity comfort conditions, as well as providing for a positive outdoor air intake (OAI) ventilation rate, are major factors in providing satisfactory IAQ.

The 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 TAB agency. This paper 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 OAI airflow rates in the design process. Final adjustments will be made by the controls contractor and the TAB contractor, but the means for providing the positive OAI ventilation rates must be part of 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 ability of the airflow and water-flow systems. The acceptance test contractor should also be responsible for making visits to the site during construction and start-up of the HVAC system, reporting any deficiencies that would prevent satisfactory completion of the acceptance tests.

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 what is currently common practice. The TAB contractor and the acceptance test contractor should have access to the DDC electronic control program, assuming they have sufficient training to make adjustments to control setpoints. In many cases the TAB contractor may also be responsible for conducting the acceptance tests.

4. The contract for the acceptance tests should be made directly with the owner. The hired contractor must then coordinate with the construction management team and other contractors to perform the tests accordingly. But once again, all acceptance tests should be witnessed by the owner's representative or the design professional.

Theodore Cohen is president of Air Conditioning Test & Balance Co., Inc., Great Neck, N.Y.

The following discussion details each aspect of the design, construction, automatic controls, testing and balancing, and final acceptance testing of an HVAC system. This paper is concerned with those factors that affect the air quality within the facility. However, before the discussion begins, I want to express my limitations as a design engineer or automatic controls expert.

I have worked as an engineer in the TAB field for many years, concerned mostly with preparing modification programs for HVAC systems that do not perform satisfactorily. These programs are designed to improve the overall performance of the ailing system. However, I am not a design engineer, so I do not intend to instruct design consultants on how to design an HVAC system. Similarly, I do not intend to direct an automatic controls contractor on how to design and install a DDC electronic control system. From my experience as a TAB contractor, I know what tools and control sequences are required to achieve the desired air quality procedures. I have a contribution to make to each of these disciplines, but I do not intend to dictate procedure to industry professionals.

DESIGN ENGINEER

The concerns of the design engineer in conceiving an HVAC system for positive control of OAI ventilation are more involved than simply selecting the minimum OAI flow rates and the exhaust ventilation rates. The following outline defines the scope of the design engineer's input.

1. The static pressure in the mixed-air plenum must be negative at all times to ensure the required intake of minimum OAI. This pressure must be held constant as long as the HVAC system is in the minimum ventilation mode, regardless of the total load and airflow rates in the system's operation (Cohen 1994).

2. The static pressure in the relief-air plenum must be positive at all times to guarantee the positive relief air discharge at all operations of the HVAC system.

3. The plenum pressures that will provide the required ventilation rates are determined by the physical characteristics of the HVAC equipment. This includes the size of the automatic dampers, the size and arrangement of the intake and discharge louvers, and the pressure of such specialty items as moisture eliminators at the OAI and bird screens at the relief-air discharges. The design engineer should have sufficient accurate data from the equipment manufacturer to allow for approximate determination of pressure levels in each plenum.

4. The design engineer should not be locked into the equipment manufacturer's basic design. Modifications to the size of the automatic dampers, moisture eliminator, or louvers may be necessary to establish the plenum pressures within a sensible control range. The design engineer may determine that, for minimum OAI and relief airflow, separate minimum damper sections should be provided.

5. An important aspect of the static-pressure analysis is the pressure drop across the return-air damper. A positive pressure in the return-air plenum and a negative pressure in the mixed-air plenum will result in a relatively high pressure drop across the damper. It is likely that the size of this automatic damper will have to be adjusted to suit the requirements of the HVAC system.

6. The design documents should detail the additional requirements necessary for the TAB and automatic controls contractors to implement the procedures described that are beyond the scope of their normal functions. Neither party can operate completely independently of the other, so the specifications should detail their obligations to ensure that their bids will be comprehensive and complete.

7. The design documents should detail the scope of the acceptance tests. If the mechanical contractor, equipment supplier, controls contractor, or any other contractor is required to assist the acceptance test contractor in establishing the required test conditions, the guidelines should be detailed clearly so that all parties will be prepared to participate if necessary. The design documents should also designate the owner's representative who will witness these tests and the documentation that will be required to certify the IAQ procedures.

CONSTRUCTION

The TAB contractor and/or the acceptance test contractor should be responsible for making periodic visits to the site to verify that the installation of automatic dampers, manual dampers, metering devices, and the controls that affect the air quality procedures are being installed properly. They will submit reports indicating any construction deficiencies that would affect the HVAC system performance or prohibit it from achieving the required air quality levels.

START-UP

Start-up is a critical point in the construction of the HVAC system. The controls contractor and the TAB contractor must coordinate their efforts. The HVAC system is on-line, the automatic control system has been activated, and the TAB is started.

The TAB contractor is calibrating the airflow at each air terminal and is verifying the operation of the static pressure controls in the OAI and the exhaust plenums. The actual operating conditions and the readout at the central processing unit must be identical. Consequently, coordination between the controls contractor and the TAB contractor is essential during this process. The TAB contractor should be trained on the details of adjusting the controls program, allowing the contractor to adjust the flow rates and pressure sensors as the TAB program requires.

FINAL TESTING AND BALANCING

When establishing the IAQ procedures in an HVAC system, there are two major concerns. First, set up and verify the minimum OAI rates and the minimum exhaust airflow rates at the HVAC unit. Second, ensure that the minimum OAI airflow rate is delivered to each occupied space.

Measuring the airflow at the HVAC unit presents a difficult task. The TAB contractor must utilize each available measurement technique to verify the flow rates. This may include pressure differentials across fixed damper and/or louver openings, coil traverse techniques, and possibly temperature differentials of mixed airstreams. It is likely that equipment manufacturers will develop procedures to simplify these measurements because they are vital factors in establishing the required IAQ.

To ensure the distribution of the minimum OAI rates to each occupied space, the design engineer is required to analyze the minimum airflow requirements for the entire HVAC system. Using these data, he or she will determine the maximum airflow requirements at each terminal. In fan-powered terminals with reheat coils, the minimum proportions or primary air can be relatively high without overcooling the space. For VAV terminals without reheat service, the proportion of cool primary air is adjusted to prevent overcooling of the space. The design engineer will make these determinations and the TAB contractor will implement the requirements in the final TAB adjustments.

FINAL ACCEPTANCE TESTS

This paper indicates that the TAB contractor and the acceptance tests contractor may be separate agencies. It is important to emphasize that the two test procedures are completely separate components of the construction, verification, and acceptance testing procedures. The TAB of the HVAC system should be completed and the final reports submitted, reviewed, and verified before beginning the acceptance tests.

If the owner's representative determines that the IAQ requirements of the design intent have been achieved, the IAQ procedures can be accepted as complying with the design and prevailing codes. If the final acceptance tests indicate that there are discrepancies between the test data and the submitted reports, then additional TAB and control adjustments may be necessary and the final acceptance tests repeated. The design documents should specify the TAB contractor's responsibility for the rebalance of systems or portions of the system, without additional payment, to satisfy the requirements of the final acceptance tests. The completed, certified test reports will be submitted to code authorities to indicate compliance with ventilation standards.

CONCLUSION

Modern HVAC systems are complex and sophisticated. Building owners are beginning to specify acceptance tests so they can be assured that the HVAC system performs as the design intended. Our concern in this analysis is with the important IAQ procedures, but the acceptance tests will assure the owner that the as-built performance of the entire system meets the design intent.

The concept of acceptance/performance tests to verify the as-built performance of an HVAC system will apply equally to modifications of existing systems. It is time for our industry to move forward and provide positive verification of system performance.

REFERENCES

Cohen, T. 1994. Providing constant ventilation in variable air volume systems. *ASHRAE Transactions* 36(5): 38-40.

IAQ 95

Practical Engineering for IAQ

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

U.S. Environmental Protection Agency

U.S. Department of Energy