SECTION 23 05 93
TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 STIPULATIONS

A. The specifications sections "General Conditions to the Construction Contract", "Special Conditions" and "Division 01 - General Requirements" form a part of this Section by this reference thereto, and shall have the same force and effect as if printed herewith in full.

1.2 ADDITIONAL RELATED DOCUMENTS

A. Testing and adjusting requirements unique to particular systems and equipment are included in the Sections that specify those systems and equipment.

B. Field quality-control testing to verify that workmanship quality for system and equipment installation is specified in system and equipment Sections.

C. Refer to the control sequences of operation and Division 23 Section "Instrumentation and Control for HVAC" for additional work required by the TAB Agent to assist the DDC system provider / sub-contractor with field measurements of airflow, water flow, or pressure.

1.3 SUMMARY

A. This Section includes testing, adjusting, and balancing HVAC systems, including the following:

1. Air Systems:

    a. Constant-volume air systems.

2. Hydronic Piping Systems:

    a. Constant-flow systems.

3. Testing, Adjusting, and Balancing of Equipment, including, but not limited to:

    a. Heat exchangers.
    b. Motors.
    c. Fans, and fan-containing equipment.
    d. Pumps.
    e. Condensing units.
    f. Heat-transfer coils.
    g. Electric duct heaters.

4. HVAC equipment quantitative-performance settings.
5. Steam systems.
6. Reporting results of activities and procedures specified in this Section.

1.4 ACCEPTABLE TESTING AND BALANCING AGENTS

A. Subject to compliance with requirements, engage one of the following TAB Agents to perform the work of this Section:

1. Air Balancing Engineers Inc. (Berwick PA)
2. Flood and Sterling Inc. (New Cumberland PA)
3. TABworks Inc. (Hershey PA)
4. Equal as approved by the Professional

1.5 DEFINITIONS

A. Adjust: To regulate fluid flow rate and air patterns at the terminal equipment, such as to reduce fan speed or adjust a damper.

B. Airflow Control Terminal: Device installed in the duct system that automatically regulates the airflow rate passing through the device. (e.g. VAV boxes, air valves, etc.)

C. Balance: To proportion flows within the distribution system, including submains, branches, and terminals, according to design quantities.

D. Deficiency: Any installation, measurement, or finding outside the tolerances allowed by the referenced testing and balancing procedural standards or project specifications.

E. Diversity: In air or hydronic systems, diversity is the term used to describe the difference in air or water volume between the prime mover (fan or pump) and sum of the terminal elements.

F. Draft: A current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person's skin than is normally dissipated.

G. Memory Stop: An adjustable mechanical device that allows a valve to be closed (for service) and limits the valve to a predetermined position when re-opened.

H. Procedure: An approach to and execution of a sequence of work operations to yield repeatable results.

I. Report Forms: Test data sheets for recording test data in logical order.

J. Shutoff Head: The dynamic measurement of a pump's total dynamic head at no flow. Performed by closing the pump discharge valve only.

K. Static Head: The pressure due to the weight of the fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.

L. Suction Head: The height of fluid surface above the centerline of the pump on the suction side.

M. System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

N. System Effect Factors: Allowances used to calculate a reduction of the performance ratings of a fan when installed under conditions different from those presented when the fan was performance tested.

O. TAB (Testing, Adjusting, and Balancing): A systematic process or service applied to HVAC systems, and other environmental systems, to achieve and document air and hydronic flow rates.

P. TAB Agent: The contractor performing the work of this Section.

Q. Terminals: In the context of a hydronic system, a device such as a coil where heat is either removed or added to the working fluid, other that the system prime movers (chillers, cooling towers, boilers, etc.).

R. Terminal Outlet or Inlet: A point where air, enters or leaves the ductwork distribution system. (e.g. diffuser, register, grille, etc.)

S. Test: A procedure to determine quantitative performance of a system or equipment.

T. Testing, Adjusting, and Balancing Agent: The entity responsible for performing and reporting the testing, adjusting, and balancing procedures.

U. AABC: Associated Air Balance Council.

V. AMCA: Air Movement and Control Association.

W. NEBB: National Environmental Balancing Bureau.

X. SMACNA: Sheet Metal and Air Conditioning Contractors' National Association.

1.6 ACTION SUBMITTALS

A. Testing and Balancing Agent Qualifications: Verification of experience and capability of the testing and balancing agent. The purpose of this submittal is to establish, in a proactive manner, that the agent proposed by the Division 23 Contractor to perform the work of this Section is qualified. The Contractor's failure to obtain approval for this submittal prevents the Contractor from utilizing the proposed service provider. Within 60 days from the Contractor's Notice to Proceed, submit 2 copies of evidence that the testing, adjusting, and balancing Agent and this Project's testing, adjusting, and balancing team members meet the qualifications specified in the "Quality Assurance" Article below. Also submit the following:

1. Resumes of the technicians anticipated to work on this project.

    a. Note: Do not submit 'generic' firm resumes or resumes of firm principals unless those individuals are proposed to do the actual testing and balancing work on site for this project.

2. A list of projects completed for each technician within the last 12 months. Include no less than three (3) client references with contact information relevant to projects completed within the last 12 months for each technician. The same project may be used more than once if multiple technicians worked on the project.
3. A list of any projects completed for this same Client Agency within the last 3 years, if any, along with the technicians who worked on those projects, and the Client Agency's contact information.

1.7 INFORMATIONAL SUBMITTALS

A. Certified Testing, Adjusting, and Balancing Reports: Submit reports prepared, as specified in this Section, on approved forms certified by the testing, adjusting, and balancing Agent.

1.8 CLOSEOUT SUBMITTALS

A. Warranty: Submit 2 copies of special warranty specified in the "Warranty" Article below.

1.9 QUALITY ASSURANCE

A. Agent Qualifications: Engage a testing, adjusting, and balancing agent that is currently certified by either AABC or NEBB.

1. The company / agency as a whole shall be certified, and at least one individually certified supervisor or technician shall be supervising or participating in the work at the project site at all times when testing and balancing activities are taking place.
2. The individually certified supervisor or technician shall be a AABC 'TBE" or NEBB Certified with a minimum of eight (8) years' experience in performing HVAC system testing, adjusting and balancing, with at least four (4) of those years in a supervisory position.
3. At least one of the on-site certified supervisors or technicians shall have performed work characteristic of this project on at least three (3) other similar projects within the last five (5) years.

B. Sub-Contracting Arrangement: The Agent shall be an independent company that is not financially affiliated with the Division 23 Contractor.

C. Certification of Testing, Adjusting, and Balancing Reports: Certify the testing, adjusting, and balancing field data reports. This certification includes the following:

1. Review field data reports to validate accuracy of data and to prepare certified testing, adjusting, and balancing reports.
2. Certify that the testing, adjusting, and balancing team complied with the approved testing, adjusting, and balancing plan and the procedures specified and referenced in this Specification.

D. Testing, Adjusting, and Balancing Reports: Use standard forms from AABC's "National Standards for Testing, Adjusting, and Balancing" or from NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems".

E. Instrumentation Type, Quantity, and Accuracy: As described in AABC national standards or in NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems," Section II, "Required Instrumentation for NEBB Certification".

F. Instrumentation Calibration: Calibrate instruments at least every 6 months or more frequently if required by the instrument manufacturer.

1.10 COORDINATION

A. The Division 23 Contractor shall coordinate the efforts of factory-authorized service representatives for systems and equipment, ATC System Installer, and other mechanics to operate HVAC systems and equipment to support and assist testing, adjusting, and balancing activities.

B. Notice: Provide 7 days' advance notice for each test. Include scheduled test dates and times.

C. Perform testing, adjusting, and balancing after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

1.11 WARRANTY

A. General Warranty: The project performance guarantee specified in this Article shall not deprive the Client Agency of other rights the Client Agency may have under other provisions of the Contract Documents and shall be in addition to, and run concurrent with, other warranties made by the Contractor under requirements of the Contract Documents.

B. Project Performance Guarantee: Provide a guarantee on AABC'S "National Standards" forms or on NEBB forms stating that AABC or NEBB will assist in completing the requirements of the Contract Documents if the testing, adjusting, and balancing Agent fails to comply with the Contract Documents. Guarantee includes the following provisions:

1. The certified Agent has tested and balanced systems according to the Contract Documents.
2. Systems are balanced to optimum performance capabilities within design and installation limits.
3. The warranty shall meet the requirements of the following program(s):

    a. AABC - National Project Performance Guarantee
    b. NEBB - Conformance Certification

PART 2 - PRODUCTS

2.1 DUCT TEST HOLES AND HOLE PLUGS

A. Refer to Division 23 Section "Air Duct Accessories" for instrument test holes for ducts constructed to pressure classes exceeding 2" w.g. positive pressure, and for ducts of welded seam and joint construction.

1. The TAB Agent shall review the Division 23 Contractor's ductwork shop drawings and shall prescribe the location, spacing, and quantity of all required instrument test holes.

B. For ducts not utilizing welded seam and joint construction and for those constructed for 2" w.g. positive pressure class or less, the TAB Agent shall provide tapered, round LDPE plastic plugs with center pull-tabs to seal holes drilled in ductwork for measuring purposes. Provide Caplugs "CPT" series or approved equal. Holes drilled in ducts shall be no larger than 1/2" diameter.

2.2 INSULATION REPAIR MATERIAL

A. Refer to Division 23 Sections "HVAC Duct Insulation" and "HVAC Piping Insulation" for insulation, jackets and tapes to repair insulation and insulation jackets removed or damaged during testing and balancing work.

B. Except where ducts are exposed in finished spaces, label the location of test holes on insulated ducts at the location of the insulation jacket repair with a permanent marker stencil or stick-on vinyl label.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine Contract Documents to become familiar with project requirements and to discover conditions in systems' designs that may preclude proper testing, adjusting, and balancing of systems and equipment.

1. Verify that balancing devices, such as balancing valves and manual volume dampers, are required by the Contract Documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.
2. Identify locations where instrument test holes are required and coordinate with the sheet metal shop drawings and coordination drawings so that the required test holes are installed prior to beginning testing and balancing operations.

B. Examine approved submittal data of HVAC systems and equipment.

1. Verify the balancing and/or flow verification requirements of the equipment provided with the manufacturers or manufacturer's representatives.
2. Electrically commutated motors (ECMs), and automatic flow balancing / flow-limiting valves are examples of equipment which often require non-standard balancing and flow measurement / verification approaches.

C. Examine equipment performance data, including fan and pump curves. Relate performance data to project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.

1. Calculate system effect factors to reduce the performance ratings of HVAC equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," Sections 7 through 10; or in SMACNA's "HVAC Systems--Duct Design," Sections 5 and 6. Compare this data with the design data and installed conditions.

D. Examine system and equipment installations to verify that they are complete and that testing, cleaning, adjusting, and commissioning specified in individual Specification Sections have been performed.

E. Examine system and equipment test reports.

F. Examine HVAC system and equipment installations to verify that indicated balancing devices, such as balancing valves and manual volume dampers, are properly installed, and their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

G. Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing.

H. Examine air-handling equipment to ensure clean filters have been installed, bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

I. Examine airflow control terminal units, such as variable air volume boxes, and fan coil and heat pump units, to verify that they are accessible and their controls are connected and functioning.

J. Examine strainers for clean screens and proper perforations.

K. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

L. Examine equipment for installation and for properly operating safety interlocks and controls.

M. Examine system pumps to ensure absence of entrained air in the suction piping.

N. Examine automatic temperature system components to verify the following:

1. Dampers , valves, and other controlled devices operate by the intended controller.
2. Dampers and valves are in the position indicated by the controller.
3. Integrity of valves and dampers for free and full operation and for tightness of fully closed and fully open positions.
4. Automatic modulating control valves are properly connected.
5. Thermostats are located to avoid adverse effects of sunlight, drafts, and cold walls.
6. Sensors are located to sense only the intended conditions.
7. Sequence of operation for control modes is according to the Contract Documents.
8. Controller set points are set at design values. Observe and record system reactions to changes in conditions. Record default set points if different from design values.
9. Interlocked systems are operating.
10. Changeover from heating to cooling mode occurs according to design values.

O. Report deficiencies discovered before and during performance of testing, adjusting, and balancing procedures.

3.2 PREPARATION

A. Complete system readiness checks. Verify, at the minimum, the following:

1. Permanent electrical power wiring is complete.
2. Hydronic systems are filled, clean, and free of air.
3. Automatic temperature-control systems are operational.
4. Equipment and duct access doors are securely closed.
5. Balance dampers are open.
6. Fire and smoke dampers are open.
7. Balancing valves are open and control valves are operational.
8. Ceilings are installed in areas where air-pattern adjustments are affected by the ceiling.
9. Air terminal inlets and outlets (grilles, diffusers, etc.) have been fitted with their specified accessories, such as dampers, neck baffles, and control grids, and have been adjusted to the required throw pattern.
10. Access to balancing devices is provided.
11. Windows and doors can be closed so design conditions for system operations can be met.
12. Variable-frequency controller startup is complete and safeties are verified.
13. Fans are operating, free of vibration, and rotating in the correct direction.
14. Strainers are pulled and cleaned.
15. Shut-off and balancing valves are verified 100% open.
16. Control Valves shall be provided with a plastic tag with the design GPM and final balance GPM value written in permanent marker . The tag shall be secured to the valve.
17. Pumps are started and proper rotation is verified.
18. Pump gage connections are installed directly at pump inlet and outlet flanges or in discharge and suction pipe prior to valves or strainers.

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in the latest edition of AABC's "National Standards for Total System Balance" or NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems", and this Section.

1. The content of this Section shall be considered supplemental to the referenced standards, however in the event of a direct conflict between the methods prescribed by this this Section and those contained in the referenced standards, the TAB Agent shall request a clarification from the Architect / Engineer. The higher cost method / procedure shall be carried in the bid price.

B. Access and Repair: Cut insulation on ducts , pipes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes as specified elsewhere in this Section and patch insulation and jacketing with new materials identical to those removed. Restore vapor barrier and finish according to the insulation Specifications for this Project.

1. Do not cut or otherwise penetrate equipment cabinets or the top of exterior ducts unless specifically permitted to do so by the Architect / Engineer.

C. Final Setting Marks: Mark equipment settings with paint or other suitable, permanent identification material, including damper-control positions , valve indicators , fan-speed-control dials, and similar controls and devices, to show final settings.

1. Control Valves shall be provided with a plastic tag with the design GPM and final balance GPM value written in permanent marker . The tag shall be secured to the valve.

D. Provide all instruments, equipment, and materials needed for tests.

3.4 RE-TESTING

A. If any deficiency in the installation of the work discovered during initial TAB operations prevents complete, accurate, and uncompromised testing, adjusting, and balancing of the systems, the TAB Agent shall report the deficiencies in writing. Any preliminary balancing work done with the deficiency still present shall will not be sufficient for acceptance, and re-testing and balancing shall be required after the deficiency has been fully corrected by the Contractor.

B. If the fan and motor sheaves furnished with the fan prove to be inadequate for properly balancing the fan, the Division 23 Contractor shall replace the sheaves at no additional Cost to the Client Agency, and the TAB agent shall re-test and balance the fan with the new sheaves.

3.5 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.

B. Prepare schematic diagrams of systems' "as-built" duct layouts.

C. Determine the best locations in main and branch ducts for accurate duct airflow measurements.

1. Do not use readouts from airflow measuring stations as report data. The Agent shall independently measure airflow rates.

D. Check airflow patterns from the outside-air louvers and dampers and the return- and exhaust-air dampers, through the supply-fan discharge and mixing dampers.

E. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

F. Verify that motor starters are equipped with properly sized thermal protection.

G. Check dampers for proper position to achieve desired airflow path.

H. Check for airflow blockages.

I. Check condensate drains for proper connections and functioning.

J. Check for proper sealing of air-handling unit components.

K. Check for proper sealing of air duct system.

L. Place systems in operation with filters installed and control systems complete and operating. Temporarily block filters to simulate dirty filter pressure drop (obtain dirty filter pressure drop from drawing schedules. If not stated, contact design engineer to obtain). Balance systems to design ratings.

M. Check flow rates for all factory set airflow control terminal units (e.g. VAV boxes) and reset if found to be incorrect.

N. Speed adjustment procedures for ECM motors controlled through an analog output from the DDC system shall be similar to that described above for direct drive fans powered through VFDs.

1. Use clamp-type electric meters that are capable of properly measuring non-linear current. Erroneous reading will occur otherwise.

3.6 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure fan static pressures to determine actual static pressure as follows:

a. Measure outlet static pressure as far downstream from the fan as practicable and upstream from restrictions in ducts such as elbows and transitions.
b. Measure static pressure directly at the fan outlet or through the flexible connection.
c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from flexible connection and downstream from duct restrictions.
d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

2. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.

a. Simulate dirty filter operation and record the point at which maintenance personnel must change filters.

3. Compare contractor document values with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur. Recommend corrective action to align design and actual conditions.
4. Obtain approval from Architect for adjustment of fan speed higher or lower than indicated speed. Make required adjustments to pulley sizes, motor sizes, and electrical connections to accommodate fan-speed changes.
5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full cooling, full heating, economizer, and any other operating modes to determine the maximum required brake horsepower.

B. Where present, adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.

1. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved.

a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets (e.g. grilles and diffusers) and calculate the total airflow for that zone.

2. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure terminal outlets and inlets without making adjustments.

1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.

D. Adjust terminal outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using volume dampers rather than extractors and the dampers at air terminal inlets and outlets.

1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
2. Adjust patterns of adjustable outlets for proper distribution without drafts.

3.7 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports with pertinent design data and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against approved pump flow rate. Correct variations that exceed plus or minus 5 percent.

B. Prepare schematic diagrams of systems' "as-built" piping layouts.

C. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:

1. Open all manual valves for maximum flow.
2. Check makeup-water-station pressure gage for adequate pressure for highest vent.
3. Set system controls so automatic valves are wide open to coils and heat exchangers.

4. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
5. Check air vents for a forceful liquid flow exiting from vents when manually operated.
6. Verify that air has been purged from the system.

D. For auto-balancing valves, and pressure-independent control valves (PICVs), record differential pressure with auto-balancing valve throttling against maximum flow.

E. For 3-way control valves, balance "bypass" flow to match "through" flow, if a calibrated manual balancing valve is shown on the bypass piping. The "through" flow shall be balanced first, with the control valve positioned for zero coil bypass. The "bypass" flow shall be balanced second, with the control valve positioned for full coil bypass.

3.8 PROCEDURES FOR CONSTANT-FLOW HYDRONIC SYSTEMS

A. Adjust pumps to deliver total design gpm.

1. Measure total water flow.

a. Position valves for full flow through coils.
b. Measure flow by main flow meter, if installed.
c. If main flow meter is not installed, determine flow by pump TDH or boiler or heat exchanger pressure drop.

2. Measure pump TDH as follows:

a. Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.
b. Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.
c. Convert pressure to head and correct for differences in gage heights.
d. Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.
e. With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved.

3. Monitor motor performance during procedures and do not operate motor in an overloaded condition.

B. Adjust flow-measuring and balancing devices installed in mains and sub-main branches to design water flows.

1. Measure flow in main and branch pipes.
2. Adjust main and branch balance valves for design flow.
3. Re-measure each main and branch after all have been adjusted.

C. Adjust flow-measuring and balancing devices installed at coils and terminal units (e.g. fin tube radiators, VAV box coils, fan coils, unit heaters, etc.) for each space to design water flows.

1. Measure flow at terminals.
2. Adjust each terminal to design flow.
3. Re-measure each terminal after it is adjusted.

4. Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.
5. Perform temperature tests after flows have been balanced.

D. Verify final system conditions as follows:

1. Re-measure and confirm that total water flow is within design.
2. Re-measure final pumps' operating data, TDH, volts, amps, and static profile.
3. Mark final settings.

E. Verify that memory stops have been set.

3.9 PROCEDURES FOR STEAM SYSTEMS

A. Measure and record upstream and downstream pressure of each piece of equipment.

B. Measure and record upstream and downstream steam pressure of pressure-reducing valves.

C. Check the setting and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record the final setting.

D. Check the settings and operation of each safety valve. Record settings.

E. Verify the operation of each steam trap.

3.10 PROCEDURES FOR STEAM TO WATER HEAT EXCHANGERS

A. Measure water flow.

B. Adjust water flow to within specified tolerances.

C. Measure inlet and outlet water temperatures, as well as the water-side pressure drop.

D. Measure inlet steam pressure.

E. Check the setting and operation of safety and relief valves. Record settings.

3.11 PROCEDURES FOR MOTORS

A. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:

1. Manufacturer, model, and serial numbers.
2. Motor horsepower rating.
3. Motor rpm.
4. Efficiency rating.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter thermal-protection-element rating.

3.12 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering- and leaving-air temperatures.

C. Record compressor data.

3.13 PROCEDURES FOR HEAT-TRANSFER COILS

A. Water Coils: Measure the following data for each coil:

1. Entering- and leaving-water temperature.
2. Water flow rate.
3. Water pressure drop.
4. Dry-bulb temperature of entering and leaving air.
5. Wet-bulb temperature of entering and leaving air for cooling coils.
6. Airflow.
7. Air pressure drop.

B. Electric-Heating Coils: Measure the following data for each coil:

1. Nameplate data.
2. Airflow.
3. Entering- and leaving-air temperature at full load.
4. Voltage and amperage input of each phase at full load and at each incremental stage.
5. Calculated kilowatt at full load.
6. Fuse or circuit-breaker rating for overload protection.

C. Refrigerant Coils: Measure the following data for each coil:

1. Dry-bulb temperature of entering and leaving air.
2. Wet-bulb temperature of entering and leaving air.
3. Airflow.
4. Air pressure drop.
5. Refrigerant suction pressure and temperature.

3.14 TOLERANCES

A. Set HVAC system airflow and water flow rates within the following tolerances:

1. Fans and Equipment with Fans: Zero to plus 10 percent, when tested with filter pressure drop simulated at dirty conditions.
2. Air System Minimum Outdoor Air Intake: 100% to 110% of design.
3. Air Outlets and Inlets (Diffusers and Grilles): Minus 10 percent to plus 10 percent.
4. Terminal Units (e.g. VAV boxes, air valves, etc.): Minus 5 percent to plus 5 percent.
5. Hydronic Flow Rate: Zero to minus 5 percent.

3.15 FINAL REPORT

A. General: Typewritten, or computer printout in letter-quality font, on standard bond paper, in three-ring binder, tabulated and divided into sections by tested and balanced systems.

B. Include a certification sheet in front of binder signed and sealed by the certified testing and balancing engineer.

1. Include a list of instruments used for procedures, along with proof of calibration.

C. Final Report Contents: In addition to report data specified in paragraphs below, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance, but do not include Shop Drawings and Product Data.
6. All required measurements and tests described in Articles above, but not listed in paragraphs below.

D. General Report Data: In addition to form titles and entries, include the following data in the final report, as applicable:

1. Title page.
2. Name and address of TAB firm.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.
9. Signature of TAB firm who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:

    a. Indicated versus final performance.
    b. Notable characteristics of systems.

12. Nomenclature sheets for each item of equipment.
13. Data for airflow control terminal units, including manufacturer, type size, and fittings.
14. Notes to explain why certain final data in the body of reports varies from indicated values.
15. Test conditions for fans and pump performance forms including the following:

    a. Settings for outside-, return-, and exhaust-air dampers.
    b. Conditions of filters.
    c. Cooling coil, wet- and dry-bulb conditions.
    d. Face and bypass damper settings at coils and other heat exchange devices.
    e. Fan drive settings including settings and percentage of maximum pitch diameter.
    f. Settings for supply-air static-pressure controller.
    g. Other system operating conditions that affect performance.

E. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:

1. Quantities of outside, supply, return, and exhaust airflows.
2. Water and steam flow rates.
3. Duct, outlet, and inlet sizes.

4. Pipe and valve sizes and locations.
5. Airflow control terminal units.
6. Airflow terminal inlets and outlets.
7. Balancing stations.
8. Position of balancing devices.

F. Air-Handling Unit, DOAS Unit, Blower Coil Unit, and Similar Air System Equipment Test Reports: For -air systems with heat transfer devices (coils, etc.) include the following:

1. Unit Data:

    a. Unit identification.
    b. Location.
    c. Make and type.
    d. Model number and unit size.
    e. Manufacturer's serial number.
    f. Unit arrangement.
    g. Discharge arrangement.
    h. Sheave make, size in inches, and bore.
    i. Sheave dimensions, center-to-center, and amount of adjustments in inches.
    j. Number of belts, make, and size.
    k. Number of filters, type, and size.

2. Motor Data:

    a. Make and frame type and size.
    b. Horsepower and rpm.
    c. Volts, phase, and hertz.
    d. Full-load amperage and service factor.
    e. Sheave make, size in inches, and bore.
    f. Sheave dimensions, center-to-center, and amount of adjustments in inches.

3. Air-Side Test Data (Indicated and Actual Values), with pressures and airflow rates presented on a diagram of the unit:

    a. Total airflow rate in cfm.
    b. Total system static pressure in inches wg.
    c. Fan rpm.
    d. Discharge static pressure in inches wg.
    e. Filter static-pressure differential in inches wg.
    f. Preheat coil static-pressure differential in inches wg.
    g. Cooling coil static-pressure differential in inches wg.
    h. Re-heating coil static-pressure differential in inches wg.
    i. Outside airflow in cfm.
    j. Return airflow in cfm.
    k. Outside-air damper position.
    l. Return-air damper position.

G. Hydronic-Coil Test Reports: As a supplement to the report for the associated air system, for hydronic coils installed in air-handling units, DOAS units, blower coil units, and similar equipment, include the following:

1. Coil Data:

    a. System identification.

b. Location.
c. Coil type.

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.
b. Air pressure drop in inches wg.
c. Outdoor-air, wet- and dry-bulb temperatures in deg F.
d. Return-air, wet- and dry-bulb temperatures in deg F.
e. Entering-air, wet- and dry-bulb temperatures in deg F.
f. Leaving-air, wet- and dry-bulb temperatures in deg F.
g. Water flow rate in gpm.
h. Water pressure differential in feet of head or psig.
i. Entering-water temperature in deg F.
j. Leaving-water temperature in deg F.

H. Refrigerant-Coil Test Reports: As a supplement to the report for the associated air system, for refrigerant coils installed in air-handling units, blower coil units, DOAS units, and similar equipment, include the following:

1. Coil Data:

a. System identification.
b. Location.
c. Coil type.

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.
b. Air pressure drop in inches wg.
c. Outdoor-air, wet- and dry-bulb temperatures in deg F.
d. Return-air, wet- and dry-bulb temperatures in deg F.
e. Entering-air, wet- and dry-bulb temperatures in deg F.
f. Leaving-air, wet- and dry-bulb temperatures in deg F.
g. Refrigerant expansion valve and refrigerant types.
h. Refrigerant suction pressure in psig.
i. Refrigerant suction temperature in deg F.

I. Electric-Coil Test Reports: For electric duct coils, and electric coils installed in air-handling units, blower coil units, DOAS units, and similar equipment, include the following:

1. Unit Data:

a. System identification.
b. Location.
c. Coil identification.
d. Capacity in Btuh.
e. Number of stages.
f. Connected volts, phase, and hertz.
g. Rated amperage.
h. Airflow rate in cfm.
i. Face area in sq. ft..
j. Minimum face velocity in fpm.

2. Test Data (Indicated and Actual Values):

a. Heat output in Btuh.
b. Airflow rate in cfm.
c. Air velocity in fpm.
d. Entering-air temperature in deg F.
e. Leaving-air temperature in deg F.
f. Voltage at each connection.
g. Amperage for each phase.

J. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:

a. System identification.
b. Location.
c. Make and type.
d. Model number and size.
e. Manufacturer's serial number.
f. Arrangement and class.
g. Sheave make, size in inches, and bore.
h. Sheave dimensions, center-to-center, and amount of adjustments in inches.

2. Motor Data:

a. Make and frame type and size.
b. Horsepower and rpm.
c. Volts, phase, and hertz.
d. Full-load amperage and service factor.
e. Sheave make, size in inches, and bore.
f. Sheave dimensions, center-to-center, and amount of adjustments in inches.
g. Number of belts, make, and size.

3. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Suction static pressure in inches wg.

K. Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

a. System, fan and air-handling unit number.
b. Location and zone.
c. Traverse air temperature in deg F.
d. Duct static pressure in inches wg.
e. Duct size in inches.
f. Duct area in sq. ft..
g. Indicated airflow rate in cfm.
h. Indicated velocity in fpm.
i. Actual airflow rate in cfm.
j. Actual average velocity in fpm.
k. Barometric pressure in psig.

L. Air-Terminal-Device Reports (Grilles, Diffusers, etc.):

1. Unit Data:

a. System and air-handling unit identification.
b. Location and zone.
c. Test apparatus used.
d. Area served.
e. Air-terminal-device make.
f. Air-terminal-device number from system diagram.
g. Air-terminal-device type and model number.
h. Air-terminal-device size.
i. Air-terminal-device effective area in sq. ft..

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.
b. Air velocity in fpm.
c. Preliminary airflow rate as needed in cfm.
d. Preliminary velocity as needed in fpm.
e. Final airflow rate in cfm.
f. Final velocity in fpm.
g. Space temperature in deg F.

M. Airflow Control Terminal (e.g. VAV box) Reports:

1. Unit Data:

a. Make and Model Number
b. System and air-handling unit identification.
c. Location and Room(s) served.
d. Inlet duct size and number of re-heat coil rows.
e. Supply outlet numbers connected from system diagram.

2. Test Data (Indicated and Actual Values):

a. Heating minimum airflow rate in cfm
b. Cooling minimum airflow rate in cfm
c. Maximum (cooling) airflow rate in cfm
d. Induced air cfm (if fan powered) during fan operation at each of the above primary air states in cfm.
e. Static pressure drop through terminal (including coil, if present) at maximum airflow.
f. Minimum and maximum flow calibration factors determined for the unit inlet velocity sensor.

N. Refrigerant Compressor and Condenser Reports: For refrigerant side of unitary systems, stand-alone refrigerant compressors, air cooled condensers, and air-cooled condensing units include the following:

1. Unit Data:

a. Unit identification.
b. Location.
c. Unit make and model number.
d. Compressor make.

e. Compressor model and serial numbers.
f. Refrigerant type and weight in lb.
g. Low ambient temperature cutoff in deg F.

2. Test Data (Indicated and Actual Values):
   a. Entering-air, dry-bulb temperature in deg F.
   b. Leaving-air, dry-bulb temperature in deg F.
   c. Control settings.
   d. Unloader set points.
   e. Low-pressure-cutout set point in psig.
   f. High-pressure-cutout set point in psig.
   g. Suction pressure in psig.
   h. Suction temperature in deg F.
   i. Condenser refrigerant pressure in psig.
   j. Condenser refrigerant temperature in deg F.
   k. Oil pressure in psig.
   l. Oil temperature in deg F.
   m. Voltage at each connection.
   n. Amperage for each phase.
   o. Kilowatt input.
   p. Crankcase heater kilowatt.
   q. Number of fans.
   r. Condenser fan rpm.
   s. Condenser fan airflow rate in cfm.
   t. Condenser fan motor make, frame size, rpm, and horsepower.
   u. Condenser fan motor voltage at each connection.
   v. Condenser fan motor amperage for each phase.

O. Heat-Exchanger Test Reports: For steam-to-water and water-to-water heat exchangers, include the following:

1. Unit Data:

   a. Unit identification.
   b. Location.
   c. Service.
   d. Make and type.
   e. Model and serial numbers.
   f. Ratings.

2. Steam Test Data (Indicated and Actual Values):

   a. Inlet pressure in psig.
   b. Condensate flow rate in lb/h.

3. Primary Water Test Data (Indicated and Actual Values):

   a. Entering-water temperature in deg F.
   b. Leaving-water temperature in deg F.
   c. Entering-water pressure in feet of head or psig.
   d. Water pressure differential in feet of head or psig.
   e. Water flow rate in gpm.

4. Secondary Water Test Data (Indicated and Actual Values):

a. Entering-water temperature in deg F.
b. Leaving-water temperature in deg F.
c. Entering-water pressure in feet of head or psig.
d. Water pressure differential in feet of head or psig.
e. Water flow rate in gpm.

P. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:

1. Unit Data:

a. Unit identification.
b. Location.
c. Service.
d. Make and size.
e. Model and serial numbers.
f. Water flow rate in gpm.
g. Water pressure differential in feet of head or psig.
h. Required net positive suction head in feet of head or psig.
i. Pump rpm.
j. Impeller diameter in inches.
k. Motor make and frame size.
l. Motor horsepower and rpm.
m. Voltage at each connection.
n. Amperage for each phase.
o. Full-load amperage and service factor.

2. Test Data (Indicated and Actual Values):

a. Static head in feet of head or psig.
b. Pump shutoff pressure in feet of head or psig.
c. Actual impeller size in inches.
d. Full-open flow rate in gpm.
e. Full-open pressure in feet of head or psig.
f. Final discharge pressure in feet of head or psig.
g. Final suction pressure in feet of head or psig.
h. Final total pressure in feet of head or psig.
i. Final water flow rate in gpm.
j. Voltage at each connection.
k. Amperage for each phase.

Q. Instrument Calibration Reports:

1. Instrument type and make.
2. Serial number.
3. Application.
4. Dates of use.
5. Dates of calibration.

3.16 VERIFICATION OF FINAL REPORT

A. The Architect / Engineer reserves the right to require a verification of the final report.

B. TAB firm test and balance engineer shall conduct the verification in the presence of Architect/ Engineer.

C. Architect/ Engineer shall randomly select measurements documented in the final report to be rechecked.

1. The rechecking shall be limited to either 10 percent of the total measurements recorded, or the extent of measurements that can be accomplished in a normal 8-hour business day on-site, whichever is less.

D. If the rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."

E. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

F. TAB firm shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes and resubmit the final report.

G. A second final inspection will be performed. If the second final inspection also fails, the Department shall contract the services of another TAB firm to complete the testing and balancing in accordance with the Contract Documents and deduct the cost of the services from the final payment.

3.17 ADDITIONAL TESTS

A. After acceptance of the final balancing report, and within one year of substantial completion, provide up to 8 hours of on-site time for additional testing and balancing to verify that balanced conditions are being maintained throughout and to correct unusual conditions. This allowance may be required over as many as two (2) separate site visits. "Additional testing and balancing" meaning work not otherwise required by the Contract Documents.

B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

END OF SECTION