

SECTION 15990 – TESTING, ADJUSTING AND BALANCING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 1 Specification Sections, apply to this Section.

1.2 WORK INCLUDED

- A. Provide all labor, instruments and materials necessary to completely test, adjust and balance all HVAC systems and equipment installed under this contract.
- B. All instruments shall be newly calibrated for this specific project.

1.3 RELATED SECTIONS

- A. Examine all drawings and criteria sheets and all other Sections of the Specifications for requirements which affect work under this Section whether or not such work is specifically mentioned in this Section.

1.4 REFERENCES

- A. Applicable provisions of the following Codes and Trade Standard Publications shall apply to the work of this Section, and are hereby incorporated into, and made a part of the Contract Documents.
- B. Material standards shall be as specified or detailed hereinafter and as follows:
 - 1. AABC MN-1 – National Standard for Testing and Balancing Heating, Ventilating and Air Conditioning Systems.
 - 2. ASHRAE 111 – Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning and Refrigeration Systems.

1.5 SYSTEM DESCRIPTION

- A. Provide under this contract the services of an independent test and balance firm that specializes in testing and balancing of HVAC systems. The following services shall be provided:
1. Balance Plan Check and Review: Review the design documents prior to commencing construction. Submit any noted questions or discrepancies in writing to the Architect.
 2. On-going job site inspections of equipment, controls and metering devices during construction to verify conformance with design specifications.
 3. Air System Balance
 4. Hydronic System Balance
 5. Control Systems Verification
 6. Special System Testing and Verification
 - a. Duct leakage testing
 - b. Sound and vibration testing
 - c. Cooling tower testing
 - d. Kitchen hood air flow testing
 - e. Smoke management systems
 7. System Performance Verification
 8. Opposite Season Test

1.6 SUBMITTALS

- A. See Section 15050 – Submittals, for submittal procedures.
- B. Submit name of testing, adjusting and balancing contractor for approval within 30 days after award of Contract.
- C. Field Reports: Indicate deficiencies in systems that would prevent proper testing, adjusting and balancing of systems and equipment to achieve specified performance.
1. Submit under provisions of Division 1 – Quality Control.
 2. Prior to commencing work, submit report forms or outlines indicating adjusting, balancing and equipment data required.
 3. Submit draft copies of report for review prior to final acceptance of Project. Provide final copies for inclusion in operating and maintenance manuals.
 4. Provide reports in letter size, 3 ring binder manual, complete with index page and indexing tabs with cover identification at front and side. Include set of reduced drawings with air outlets and equipment identified to correspond with data sheets and indicating thermostat locations.
 5. Include detailed procedures, agenda, sample reports forms and copy of AABC National Project Performance Guaranty prior to commencing system balance.
 6. Test Reports: Indicate data on AABC MN-1 forms, forms prepared following ASHRAE 111, NEBB forms, or forms containing information indicated in Schedules.

7. Include the following on the title page of each report.
 - a. Name of Testing, Adjusting and Balancing Agency.
 - b. Address of Testing, Adjusting and Balancing Agency.
 - c. Telephone number of Testing, Adjusting and Balancing Agency.
 - d. Project name.
 - e. Project location.
 - f. Project Architect.
 - g. Project Engineer.
 - h. Project Contractor.
 - i. Report date.

- D. Project Record Documents: Record actual locations of all water systems balancing valves and rough setting.

1.7 DEFINITIONS

- A. AABC: The Associated Air Balance Council is a non-profit association of independent, certified agencies specializing in testing and balancing HVAC systems.
- B. ASHRAE: American Society of Heating, Refrigerating and Air Conditioning Engineers.
- C. HVAC: Heating, Ventilating and Air Conditioning.
- D. TAB: Testing, Adjusting and Balancing of HVAC Systems to meet design objectives and obtain optimum system performance.
- E. NEBB: National Environmental Balancing Bureau.
- F. TBE: Test and Balance Engineer is an individual certified by AABC as having a degree in Engineering and (3) years of test and balance experience, or (5) years of background in the air conditioning field and (5) years continuous field experience in testing and balancing work. The TBE must also pass the AABC Test and Balance Engineer Certification Examination.

1.8 AGENCY QUALIFICATIONS

- A. Testing and balancing agency shall be a member of AABC or NEBB with a minimum of five (5) years of documented experience.
- B. An AABC certified NEBB certified testing and balancing person shall be responsible for certification of the total work of this section.
- C. All work shall be performed in accordance with AABC National Standards. If these specifications set forth more stringent requirements than the AABC National Standards, the more stringent specifications shall prevail.

1.9 QUALIFICATION SUBMITTALS

- A. Testing and balancing agency shall submit a company resume listing personnel and project experience in the field of air and hydronic system balancing.
- B. Testing and balancing agency shall submit an inventory and calibration data of all instruments and devices in possession of the balancing agency to enable the Owner or his representative to evaluate the balancing agency's performance capability.
- C. The testing and balancing agency shall submit to the Owner or the Owner's representative, upon acceptance of the contract, an AABC or NEBB "Quality Assurance Guaranty."
- D. Within (30) days after acceptance of the contract, the testing and balancing agency shall submit to the Design Engineer a working agenda which will include procedures for testing and balancing each type of air and water flow system. The Test and Balance Report format will also be submitted indicating data to be recorded.

1.10 CONTRACT DOCUMENTS

- A. Within (30) days after selection of the Test and Balance Agency, the Construction Manager shall provide the agency with the following:
 - 1. Construction Drawings
 - 2. Equipment Specifications
 - 3. Equipment Submittals
- B. The testing and balancing agency shall be provided the following as issued or received:
 - 1. Change Orders/Current Updated Construction Mechanical Drawings Incorporating All Revisions
 - 2. Equipment Manufacturer's Submittal Data
 - 3. Mechanical/Air Conditioning Contractor's Shop Drawings
 - 4. Temperature Control Drawings
 - 5. Project Schedule

1.11 NOTIFICATION AND SCHEDULING

- A. A prebalance conference shall be held prior to job start as scheduled by the Owner or Owner's representative. Attendees at the meeting shall include representatives of the test and balance agency, Construction Manager, Mechanical Contractor, Control Contractor, Owner and Mechanical Engineer.
- B. The schedule for testing and balancing the HVAC system shall be established by the Owner or Owner's representative, in coordination with the testing and balancing agency on a critical path network.

- C. The testing and balancing agency is responsible for initiating this continuing coordination to determine schedule for final testing and balancing services.
- D. It will be necessary for the testing and balancing agency to perform its services in close coordination with the Mechanical Contractor, with all scheduling and deficiencies reported through the Owner or Owner's representative.
- E. Before testing and balancing commences, the testing and balancing agency shall receive notification, in writing, from the Mechanical Contractor that the system is operational, complete, and ready for balancing.
- F. A completed system exceeds physical installation: the Mechanical Contractor shall certify that all prime movers, fans, pumps, cooling towers, boilers, etc., are installed in good working order, and that full load performance has been preliminary tested.
- G. The Mechanical Contractor shall certify in writing, that all equipment has been checked, started, adjusted by the manufacturer, and operated for the specified period of time.

1.12 COORDINATION WITH OTHER TRADES

- A. To bring the HVAC system into a state of readiness for testing, adjusting and balancing, the Mechanical Contractor shall perform the following:
 - 1. Air Distribution Systems
 - a. Ensure that all splitters, extractors, volume, smoke and fire dampers are properly located and functional. Dampers serving requirements of smoke, minimum and maximum outside, return, relief, and exhaust air shall provide tight closure and full opening, with a smooth and free operation.
 - b. Verify that all supply, return, exhaust, and transfer grilles, registers and diffusers are installed and operational.
 - c. Ensure that air handling systems, units, makeup air units and associated apparatus, such as heating and cooling coils, filter sections, access doors, etc. are blanked and/or sealed to eliminate excessive bypass or leakage of air.
 - d. Ensure that all fans (supply, return, relief, and exhaust) are operating and free of vibration. All fans and drives shall be checked for proper fan rotation and belt tension. Overload protection shall be of proper size and rating. A record of motor current and voltage shall be made to verify that the motors do not exceed nameplate rating.
 - e. Make any necessary changes to the sheaves, belts, and dampers, as required by the testing and balancing agency, at no additional cost to Owner.
 - f. Install clean filters prior to testing.
 - 2. Water Circulating Systems
 - a. Check all pumps to verify pump alignment and rotation.

- b. Ensure that systems are clean, with the proper strainer screens installed for normal operation.
 - c. Check all pump motors for current and voltage, to ensure that motors do not exceed nameplate rating.
 - d. Provide overload protection of proper size and rating.
 - e. Ensure that all water circulating systems shall be clean, full and free of air, that expansion tanks are set for proper water level, and that all air vents are installed at high points of systems and are operating.
 - f. Check and set operating temperature of heat exchangers to design requirements.
- B. The Temperature Control Contractor shall perform the following:
- 1. Verify that all control components are installed in accordance with project requirements and are functional, including all electrical interlocks, damper sequences, air and water resets, and fire and freeze stats.
 - 2. Verify that all controlling instruments are calibrated and set for design operating conditions.
 - 3. Calibrate room thermostats after installation and before the thermostat control verification tests are performed. The test and balance agency shall verify the accuracy of final settings by taking temperature readings. The readings shall be in a typical conditioned space for each separately controlled zone.
 - 4. The Control Contractor shall allow sufficient time in the project to provide assistance and instruction to the testing and balancing agency in the proper use and setting of control components such as, but not limited to, computers, static pressure controllers or any other device that may need setpoints changed so that the testing and balancing work can be performed.
- C. The Mechanical Contractor, Temperature Control Contractor, and the suppliers of the HVAC equipment shall all cooperate with the testing and balancing agency to provide all necessary data on the design and proper application of the system components. In addition, they shall furnish all labor and materials required to eliminate any system deficiencies.
- D. In coordination with the Construction Manager, the testing and balancing agency shall arrange for an area of ample size and convenient location for storage of tools, equipment, and other items as required.

PART 2 - PRODUCTS

2.1 GENERAL

- A. The Construction Manager shall procure the services of an independent Balancing and Testing Contractor who specializes in the balancing and testing of heating, ventilating and air conditioning systems to balance and adjust, all moving equipment and air distribution and exhaust systems and test all water systems and equipment, as herein specified. All work by the Balancing Contractor shall be done under direct supervision of a qualified heating and

ventilating Engineer employed by the Balancing Contractor. Balancing Contractor shall submit credentials and be approved prior to Contract Award.

- B. Balance and testing shall not begin until all HVAC systems have been completed and are in full working order, as determined by the Architect. Where construction is phased, the Testing and Balancing Contractor shall submit a plan of action which outlines how each phase will be balanced and how, when completed, the entire system will be verified to be tested and balanced. The Balancing Contractor shall coordinate his work with the HVAC and ATC Contractors, shall place all heating, ventilating and air conditioning systems and equipment into full operation, and continue the operation of same during each working day of adjusting and balancing.
- C. The Balancing Contractor shall perform all tests as hereinafter specified, compile the test data, and submit five (5) copies of the complete test data to the Construction Manager for forwarding to the Architect for evaluation and approval.
- D. The Construction Manager shall award the test and balance contract to the approved agency at the beginning of construction of the project to allow the Balancing Contractor to schedule this work in cooperation with the HVAC Contractor, ATC Contractor and other Trades involved and comply with completion data and requirements, as well as provide a list of areas where special requirements for balancing devices (dampers, valves) might occur.
- E. The Balancing Contractor shall provide all testing instruments used for balancing air and water systems. Testing instruments shall have been calibrated within a period of six (6) months prior to balancing. Types, serial numbers and dates of calibration of all instruments shall be listed in the final air and water balance reports herein specified.
 - 1. The Balancing Contractor shall provide all Certificates of Calibration for all instruments used for the balancing of the air and water systems. Calibration shall be traceable to NIST standards for instrument calibration.
- F. The Architect's, Engineer's and Owner's designated representatives shall be notified minimum five (5) days in advance of proceeding with balancing work to allow time for the witnessing of the testing, balancing and adjusting.
- G. The Balancing Contractor shall provide all manpower, instruments, temporary connections and all other materials required to accomplish the balancing and testing as hereinafter specified. In the case of phased construction, the action plan shall include an explanation of all temporary facilities and their effect on the overall system.
- H. The Balancing Contractor shall balance cooling systems in the air conditioning season and heating systems in the heating season. **This requirement is mandatory.**
- I. In the event it becomes necessary for the Owner to balance the HVAC systems correctly, after the balancing is complete, the cost of this work will be back charged to the Balancing Contractor.

2.2 SCHEMATIC SYSTEM DRAWINGS

A. Piping Systems

1. The Balancing Contractor shall prepare schematic diagrammatic drawings for the following systems:
 - a. Chilled Water
 - b. Hot Water
 - c. Process Chilled Water
 - d. Condenser Water
2. The drawings will be 1-line schematic representation of the systems as they are installed, indicating all major automatic control valves, strainers, pressure reducing valves, etc., as well as all water flow and energy meters.
3. The diagrams shall indicate, in addition to the graphic representation requirements outlined above, all pressure drops (design conditions and actual conditions) of each valve, strainer, meter, etc., as well as all flows at each meter.
4. The use of the Engineer's construction drawing diagrams can be utilized by the Balancing Contractor as the base of the diagrams required. However, the drawings will have to be updated by the Balancing Contractor for field modifications which may have occurred during construction.

B. Ductwork Systems

1. The Balancing Contractor shall prepare schematic diagrammatic drawings for the following:
 - a. Supply air systems (all units)
 - b. Return air systems (all units)
 - c. All exhaust air systems including specialized exhaust systems
2. The drawings will be 1-line airflow schematics emanating from the air handling equipment, through shafts, to the first major split of duct branches on each floor. The drawings will indicate the air quantities measured at these major branches, pressure drop and any other pertinent information deemed necessary by the Architect.
3. In addition to the duct schematic drawings, the Balancing Contractor shall prepare individual schematic drawings for each air handling unit indicating the pressure drop of each component of the unit, including the discharge plenum and unit duct discharge and shall prepare composite schematic drawing of all "special pressure" rooms or spaces which shall show on one drawing, the supply, return and/or exhaust systems, flow rates (design and actual) and final offset pressure/CFM.
4. Balance "special pressure" spaces to the minimum differential pressure as scheduled:
 - a. Operating room +0.025" Water Gauge
 - b. Surgical Cystoscopic room +0.025" Water Gauge
 - c. Protective isolation +0.025" Water Gauge
 - d. Infectious isolation -0.025" Water Gauge

		(relative to Anti-room)
e.	Infectious Anti-room	-0.010" Water Gauge
		(relative to Corridor)
f.	Protective anti-room	-0.010" Water Gauge
		(relative to Corridor)
g.	Bronchoscopy	-0.025" Water Gauge
h.	Pharmacy	+0.025" Water Gauge
i.	Others Positive	+0.025" Water Gauge
j.	Others Negative	-0.025" Water Gauge

- C. The intent of the required documentation would be to clearly indicate the balancing and performance of the systems as they are installed. Furthermore, the above-required information will be utilized by the Owner for future renovation and/or alterations of the various systems. Therefore, the drawing content and presentation will be submitted to the Architect for review prior to actual commencement of the work. In the case of phased construction, the schematics shall indicate the limit of each phase and any temporary measures taken to obtain system performance.
- D. The drawings shall be produced on AutoCAD (latest version) and a disc and one (1) set of reproducible vellums shall be submitted to the Owner through the Architect, for his use. All costs associated with the production of the documents shall be included under the Balancing Contractor's contract.
- E. Test Code Drawings
1. Each report shall contain a single line drawing or drawings of the air distribution system with the fan system, applicable zoning, etc., indicated. Each and every outlet supply and return shall be indicated on this drawing by a number corresponding to the number of the outlet test sheet.

2.3 TEST FORMS USED BY BALANCING ENGINEERS AND TECHNICIANS SHALL BE SET UP TO INCLUDE THE FOLLOWING INFORMATION:

- A. Each sheet shall have the job name and address, the name of the Balancing Contractor, Owner, Architect and Engineer, the instruments used to perform the test, and the name of the test Technician, date and time of test, outside db/wb temperatures.
- B. All forms shall be submitted on a standard 8 1/2" by 11" good quality paper, bound together to form a complete report. All forms shall be submitted in typewritten form; handwritten forms are not acceptable. Cover of first sheet shall list the name of the job and the location of same. Copies of all forms shall be submitted to the Architect for review and acceptance prior to the work beginning.

C. Diffuser, Grille, Register, Fume Hoods, and All Types of Air Terminal Test Sheets

1. Each sheet shall be arranged in columns and all final sheets shall show the following data:
 - a. Fan system.
 - b. Room number or area designation.
 - c. Outlet code number which shall correspond to code number.
 - d. Size of outlet - manufacturer's listed data.
 - e. Type of outlet per manufacturer's model designation.
 - f. Manufacturer of outlet.
 - g. Manufacturer's effective area for each size.
 - h. Schedule FPM and required CFM of each outlet, individually for heating and cooling.
 - i. Test resultant FPM and CFM of each outlet, individually for heating and cooling.
 - j. Testing, setting and report of CFM settings for each terminal box, including pressure drop at each setting (heating and cooling).
 - k. All rooms/spaces with ducted supply and return/exhaust are to have supply, return/exhaust quantities shown on the same sheet. All rooms are to have air quantities for supply, return/exhaust listed per individual room. Supply, return/exhaust readings shall be listed sequentially, with final CFM offset, or room pressure clearly identified.

2. Each exhaust hood that is exhausted by ductwork shall be tested, adjusted and balanced in coordination with the hood manufacturer, ATC Contractor, HVAC Contractor and fume hood controls manufacturer. Verify manufacturers procedures and schedule testing with the required contractors prior to proceeding. Submit and coordinate the proposed testing procedure with the Owner's representatives and engineer prior to proceeding. Testing of face velocity shall be performed using a multipoint thermal anemometer device that is professionally calibrated prior to testing. Face velocity shall be measured at a minimum of one (1) reading per each square foot of open sash. Readings shall be recorded individually and averaged over the entire openings.
 - a. Constant Volume Fume Hoods (With Fan)
 - 1) Test exhaust fan as described.
 - 2) Set the sash in full open position.
 - 3) Measure airflow CFM and face velocity across open sash per ASHRAE 110 and ANSI Z9.5.
 - 4) Resheave fan as required to achieve desired CFM exhaust.

 - b. Constant Volume Fume Hoods
 - 1) Set exhaust valve to desired exhaust rate (CFM).
 - 2) Set sash in full open (or normal operating) position.

- 3) Measure airflow CFM and face velocity across open sash per ASHRAE 10 and ANSI Z9.5.
- 4) Adjust exhaust valve setting to achieve desired CFM exhaust.
- 5) Calibrate exhaust flow transducer reading to match measured exhaust CFM.

D. Air Handling Equipment Test Sheets

1. Each sheet shall contain two (2) columns, one (1) for specified conditions and one (1) for test conditions obtained. When units tested are variable air volume (VAV) data shall be submitted for maximum and minimum air flows.
2. All final sheets shall list the following data:
 - a. System fan number.
 - b. Fan manufacturer and model number.
 - c. Fan curve.
 - d. Total CFM.
 - e. Return air, CFM.
 - f. Outside air, CFM.
 - g. Total static pressure.
 - h. Suction static pressure.
 - i. Discharge static pressure.
 - j. Motor manufacturer.
 - k. Motor size, voltage, phase and RPM.
 - l. Amperage nameplate rating.
 - m. Final operating amperage.
 - n. Fan RPM (supply).
 - o. Fan RPM (return).
 - p. Component pressure drop.

E. Exhaust and Ventilating Fan Test Sheets

1. Each sheet shall contain in two (2) columns, one (1) for specified conditions and one (1) for test conditions obtained. Variable volume systems data is to be submitted for both maximum and minimum air flows.
2. All final sheets shall list the following data:
 - a. Exhaust fan system and exhaust fan number.
 - b. Fan manufacturer.
 - c. Fan curve.
 - d. Size and model.
 - e. Motor HP, voltage and phase.
 - f. Changes made or recommended.
 - g. Amperage nameplate rating.
 - h. Final operating amperage.
 - i. Fan RPM.
 - j. Total CFM.
 - k. Suction static, discharge static, total static.

F. Temperature Test Sheets (As Applicable For Each Air Handling Unit)

1. The temperature test sheets shall list both the specified conditions and the actual operating conditions in opposite columns. Items listed on this sheet shall be as follows:
 - a. Cooling Cycle: Chilled Water
 - 1) Entering air db and wb temperature.
 - 2) Leaving air db and wb temperature.
 - 3) Outside air db and wb temperature.
 - 4) Chilled water supply temperature.
 - 5) Chilled water return temperature.
 - 6) Unit discharge temperature.
 - b. Heating Cycle: Hot Water/Steam
 - 1) Entering air db temperature.
 - 2) Leaving air db temperature.
 - 3) Entering and leaving coil water temperatures/entering steam pressure.
 - 4) Outside air db and wb temperatures.
 - 5) Unit discharge temperature.

G. Pump Test Sheets

1. For each pump the following data shall be listed:
 - a. Pump number and system name.
 - b. Pump manufacturer and model number.
 - c. Pump curve.
 - d. Motor HP and RPM.
 - e. Voltage - Nameplate, test.
 - f. Amperage - Nameplate, test.
 - g. GPM, rated, tested.
 - h. Pressure rise rated, test.
 - i. Inlet pressure, outlet pressure.
 - j. Inlet temperature.
 - k. Shut-off pressure.

H. Coil and All Other Heating Element Test Sheets (Unit Heaters, Reheat Coils, Reheat Boxes, Cabinet Unit Heaters)

1. For each element both the specified and test conditions shall be listed:
2. Inlet water temperature (hot/chilled water).
3. Inlet air temperature.
4. Outlet water temperature (hot/chilled water).
5. Outlet air temperature.
6. Pressure drop through unit.

- I. Velocity and Pressure Test Sheets for Main and Branch Ducts
 1. Duct location or designation.
 2. Duct size.
 3. Number of velocity readings.
 4. Duct average velocity.
 5. Total CFM.
 6. Duct average static pressure.

- J. Calibration of air flow measurement stations in cooperation and in conjunction with ATC contractor, provide all necessary pitot tube traverses and/or other air measurements necessary to field verify the accuracy of all installed air flow measurement stations at all air handling units, exhaust air handling units, return fans and cuts. Calibration readings shall be taken at 180%, 75%, 50% of rated flow and a curve shall be prepared that indicates any deviation between air flow station readings and field readings at these floors.

PART 3 - EXECUTION

3.1 AIR SYSTEM BALANCING AND TESTING PROCEDURES

- A. The Balancing Contractor shall perform the following tests, and balance all systems in accordance with the following requirements after clean filters are installed in all filter banks before tests are performed:
 1. Test and adjust blower RPM or blade pitch angle on vane axial fans to achieve design requirements.
 - a. Test and record motor full load ampere.
 - b. Make pitot tube transverse of main supply, return and exhaust air ducts to obtain design CFM at fans.
 - c. Test and report system static pressure, suction and discharge.
 - d. Test and adjust system for design CFM recirculated air.
 - e. Test and adjust system for design CFM outside air.
 - f. Test and record entering and leaving air temperatures (db-wb cooling and db heating).
 - g. Adjust all main supply, return and exhaust air ducts to proper design CFM.
 - h. Adjust all zones and branches to proper design CFM, supply, return and exhaust systems.
 - i. Test and adjust each diffuser, grille, register, and constant volume box to within $\pm 5\%$ of design requirements.
 - j. Test and adjust all special pressure rooms to maintain pressure relationship indicated on the drawings. Note that air quantities on the drawing may have to be changed to satisfy the pressure relationship.
 - k. Identify and list size, type and manufacturer of diffusers, grilles, registers, and terminal volume boxes. Include information regarding coils where applicable.

- l. Measure air quantities in main and branch ducts by traversing entire cross sectional area of duct with pitot tube. Ducts having velocities of 1000 feet per minute or more shall be measured with inclined manometers (draft gauge) or magnehelic gauges; ducts having velocities of less than 1000 per feet per minute shall be measured with micromanometers, hook gauges, or similar low pressure instruments. Openings in ducts for pitot tube insertion shall be sealed with snap-in plugs and covered with duct tape after air balance is complete. Diffuser, grille and register air quantities shall be determined by direct reading velocity meters in accordance with the manufacturer's recommendations.
- m. Identify, adjust, balance and measure air quantities in all types of hoods or exhaust "trunks", where applicable. Identify systems by fan designation and room name.
- n. Obtain design air quantities in main ducts by adjusting fans. Branch duct air quantities shall be adjusted by volume dampers. Dampers shall be permanently marked after air balance is complete to enable them to be restored to their correct position if disturbed at any time.
- o. As part of this Contract, the Balancing Contractor shall change the pulleys, belts, and fixed sheaves to provide for permanent sheaves, pulleys and belts, based on the final balancing, in order to ensure proper air delivery of the various systems. The Balancing Contractor shall also make all necessary adjustments to vane axial fan blade pitch angle to achieve required airflow.
- p. In cooperation with the ATC Contractor, determine the proper setpoint for all automatically operated dampers, air valves, static pressure sensors, inlet vane actuators, or other variable or controllable devices requiring coordination between Balancing Contractor and ATC Contractor. The Balancing Contractor shall determine the lowest system static setpoint possible that will deliver the proper air quantities to all outlets at the maximum cooling condition, and will adjust the fan system to operate at its most economical setting to achieve this static setpoint. Fans will be adjusted to the most economical setting by adjusting the fan speed (or blade pitch angle) with any variable volume devices in their maximum or wide-open position. Final static pressure setpoints are to be recorded in the test and balance report and listed for each unit.
- q. Any dampers, safing of baffles required for final balancing, as determined by the Balancing Contractor the Architect, will be provided by the HVAC Contractor to ensure proper performance, at no extra cost to the Owner.

3.2 WATER SYSTEM BALANCING AND TESTING PROCEDURES

A. Preparation of the System for Water Testing and Balancing

1. The Balancing Engineer or Technician must prepare the water system for balancing in the following manner:
 - a. Open all valves to full position, including coil stop valves, return line balancing cocks and close all bypass valves, including system differential pressure bypass valve if applicable.
 - b. Remove, clean and/or replace all strainers.
 - c. Examine water in system to determine if it has been treated and is clean.
 - d. Check pump rotation, correct if necessary.
 - e. Check expansion tank to make sure it is not air bound and that the system is full of water.
 - f. Check all air vents at high points of water systems to make sure they are installed properly and are operating freely.
 - g. Make certain all air is removed from circulating system.
 - h. Check operation of differential automatic bypass valves, set valve in closed position.
 - i. Check and set operating temperature of systems to design requirements.
 - j. Complete air balancing must have been accomplished before water balance is begun.
 - k. Set all temperature controls so that all cooling coils are calling for full cooling and heating coils are calling for full heating.
 - l. Set hot and chilled water systems to proper GPM delivery.
 - m. Check leaving water temperature, return water temperature and pressure drop through all coils. Reset to correct design temperatures.
 - n. Balance each hot water coil, chilled water coil and all other heating elements.
 - o. After making adjustments to coils and other waterflow elements, reset settings at pumps, as required to obtain proper flows.
 - p. Determine system operating differential pressure and, in conjunction with the ATC Contractor, set any differential pressure valves for proper operation.
 - q. Upon completion of flow readings and coil adjustments, and after water balance is complete, permanently mark all balancing valves, cocks and flow meters so that they can be restored to their correct position if disturbed. Properly set memory stops on all balancing valves so equipped.
 - r. After the Balancing Contractor sets all waterflow balancing devices to proper design GPM, he shall mark the GPM flows on the piping schematic drawings.
 - s. The Balancing Contractor shall determine the lowest possible differential pressure control point possible for all variable speed pumping systems and for all differential pressure bypass control valves. In systems that have both variable speed pumping controlled by differential pressure and a differential pressure bypass valve, the Balancing Contractor shall assure, in conjunction with the ATC Contractor, that a minimum of 3 psig difference in setpoints is maintained between the two control settings with the differential pressure setpoint for the variable speed pumping system being the lower of the two settings.

3.3 INSTALLED ELEMENT TEST PROCEDURES

- A. Element identification (location or number designation).
- B. Required temperature drop corrected for actual entering air and water conditions.
- C. Element adjusted until the required drop is obtained.

3.4 CONTROL SYSTEMS VERIFICATION

- A. Verify all control devices are properly connected.
- B. Verify all dampers, valves and other controlled devices are operated by the intended controller.
- C. Verify all dampers and valves are in the position indicated by the controller (open, closed, modulating).
- D. Verify the integrity of valves and dampers in terms of tightness of close off and full open positions.
- E. Check all valves are properly installed in the piping system in relation to direction of flow and location.
- F. Check calibration of all controllers.
- G. Verify the proper application of all normally open and normally closed valves.
- H. Check the location of all thermostats and humidistats for potential erratic operation from outside influences such as sunlight, drafts or cold walls.
- I. Check the locations of all sensors to determine whether their position will allow them to sense only the intended temperatures or pressures of the media. Control Contractor will relocate as deemed necessary by the testing and balancing agency.
- J. Check the sequence of operation that any control mode is in accordance with approved shop drawings. Verify that only minimum simultaneous heating and cooling occurs. Observe that the control valves at the boiler are properly sequenced.
- K. Verify all controller setpoints meet the design intent.
- L. Check all dampers for free travel.
- M. Verify the operation of all interlock systems.
- N. Perform all systems verification to ensure the safety of the system and its components.

3.5 SPECIAL SYSTEMS TESTING

A. Duct Leakage Testing

1. Testing shall be conducted before external insulation is applied and before ducts are connected.
2. Mechanical Contractor to close off and seal all openings in the duct section to be tested.
3. Each section shall be tested by the Mechanical Contractor in accordance to the leakage class as specified under Section 15815 and SMACNA Standards. All tests shall be witnessed and documented by the TAB Contractor.

B. Sound and Vibration Testing

1. Sound

- a. Sound level readings shall be taken in at least (10) locations in the building with an octave band analyzer.
- b. The test data for each area will be recorded on noise criteria curves indicating the decibel level read in each frequency band, the NC level required, and the NC level measured.
- c. Readings shall be taken at night in order to reduce the ambient noise level.
- d. The testing and balancing agency will submit the test data and test equipment data to the Architect and Engineer for their review and include the approved forms in the testing and balancing report.

2. Vibration

- a. Vibration field measurements shall be taken as required for each circulating water pump, cooling towers, chillers, air handling unit, and fan driven by a motor over 10 HP.
- b. Readings shall include shaft alignment, equipment vibration, bearing housing vibration, foundation vibration, and building structure vibration.
- c. Readings shall be made using portable equipment capable of filtering out unwanted frequencies.
- d. Maximum vibration at any point listed above shall not exceed criteria listed in the ASHRAE Handbook, HVAC Systems and Application, Chapter 52 "Sound and Vibration Control", Table 26 "Equipment Vibration Criteria", unless otherwise specified. Readings shall be taken with vibration isolation blocked solid to the foundation.

C. Cooling Tower Testing

1. Test temperature of cold water leaving the cooling tower (LWT).
2. Test temperature of hot water entering the cooling tower (EWT).
3. Test wet bulb temperature of air entering the cooling tower (EWB).
4. Test dry bulb temperature of air entering the cooling tower (EDB).

5. Test temperature of the make up water entering the tower (Tmu) if not shut off during testing.
6. Test flow rate of the make-up water entering the tower (GPMct).
7. Test flow rate of water recirculating through the cooling tower (GPMct).
8. Test flow rate of the blowdown (bleed) discharged from the tower (GPMb) if not shut off during testing.
9. Test power input to the fan motor(s) (kW).
10. Test pump discharge pressure (P).
11. Test Barometer pressure (Pb).

D. Kitchen Hood and Dishwasher Exhaust Testing

1. Turn on exhaust fan and adjust airflow to provide the specified average hood face velocity at hood opening.
2. Calculate and record exhaust volume (CFM) by measuring airflow in exhaust duct just forward of exhaust fan.
3. Measure air velocity using pitot traverse method. Multiply average duct velocity by the cross sectional area of the duct.
4. Measure and record each face velocity reading taken at 4" increments (total horizontal increments shall be divisible by [3] and vertical increments divisible by [2]) over the entire door opening.
5. Use an electrically operated anemometer, direct reading, with graduations from 0 to 200FPM. Calculate and record the average face velocity (FPM) by averaging all velocity readings.
6. Calculate and record the volume (CFM) of exhaust air at hood face by multiplying the calculated average face velocity by the square feet of the hood opening.
7. Compare with exhaust volume at exhaust fan.
8. Verify the make-up air system supplies the proper amount of air to keep the kitchen a constant pressure with the exhaust system in high speed.
9. Re-accomplish test of average face velocity. Adjust hood baffles, fan drives, and other parts of the system as necessary to provide the specified average face velocity and the specified auxiliary air supply percentage.
10. Re-accomplish tests and adjust the system until kitchen hood performance is in compliance.

E. Smoke Management System Testing

1. Obtain the Final Construction Life Safety Documents from the Construction Manager. Identify the location and extent of each individual on-floor smoke zone and the adjoining partitions with adjacent smoke zones.
2. Utilizing the Contractor All-Trade Coordination drawings, identify and develop a matrix by smoke zone of all smoke dampers and air terminal boxes within each smoke zone.
3. In cooperation with the ATC Contractor, determine the proper setpoint for all smoke dampers and air terminal boxes by individual smoke zone to develop a negative pressure differential of 0.05" w.g. between the assigned "Area of Incident" and adjacent smoke zones. Continue setup work thru building unit each smoke zone has been individually set as the "Area of Incident" and smoke management settings

established for all terminal boxes. Refer to Section 17000 – Automatic Temperature Controls, para. 5.2R, Engineered Smoke Management Systems, for sequencing of the terminal boxes and smoke dampers.

4. In conjunction with the Construction Manager, develop a schedule for the full system testing of the Smoke Management System. This testing shall include the ATC Contractor, Sheet Metal Contractor, Electrical Contractor and Fire Alarm Contractor.
 - a. A minimum of two (2) weeks advance notification of the testing schedule shall be provided to the Owner, Architect, Engineer and City of Portland Inspectional Services to allow the parties to witness the Smoke Management System testing if so desired.
 - b. Via the Fire Alarm System, an alarm signal shall be sent to the ATC System annunciating a Fire Condition in an individual smoke zone. The ATC System shall then initiate the Smoke Management System sequence with the “Alarmed” smoke zone designated as the “Area of Incident”.
 - c. Once the Smoke Management System is initialized, the Balancing Contractor shall verify pressure differentials with the adjacent smoke zones.
 - d. Testing shall continue until each smoke zone has individually been identified as the “Alarmed” smoke zone and the proper pressure relationships verified with the adjacent smoke zones.
5. Provide Final Report by smoke zone indicting the terminal box settings and final pressure differentials with adjacent smoke zones.

3.6 SYSTEM PERFORMANCE VERIFICATION

- A. At the time of final inspection, the test and balance agency shall recheck, in the presence of the Owner's representative, specific and random selections of data, air quantities, and air motion recorded in the Certified Report.
- B. Points and areas for recheck shall be selected by the Owner's representative.
- C. Measurement and test procedures shall be the same as approved for work forming basis of Certified Report.
- D. Selections for recheck, specific plus random, will not normally exceed 25% of the total number tabulated in the report, except that special air systems may require a complete recheck for safety reasons.
- E. If random tests elicit a measured flow deviation of 10% or more from that recorded in the Certified Report listings, by 10% or more of the selected recheck stations, the report is rejected, all systems shall be readjusted and tested, new data recorded, new Certified Report submitted, and new inspection tests made, all at no additional cost to Owner.
- F. Following system verification of the Certified Report by the Owner's representative, the settings of all valves, splitters, dampers, and other adjustment devices shall be permanently

marked by the testing and balancing agency so that adjustment can be restored if disturbed at any time. Devices shall not be marked until after system verification.

3.7 OPPOSITE SEASON TEST

- A. The testing and balancing agency shall perform an inspection of the HVAC system during the opposite season from that in which the initial adjustments were made. The testing and balancing agency shall make any necessary modifications to the initial adjustments to produce optimum system operation.

3.8 RECORD AND REPORT DATA

- A. The test and balance report shall be complete with logs, data and records as required herein. All logs, data and records shall be typed on white bond paper and bound. The report shall be certified accurate and complete by the testing and balancing agency's certified balancing engineer.
- B. Six (6) copies of the test and balance report are required and shall be submitted to the Owner or the Owner's representative.
- C. The report shall contain the following general data in a format selected by the testing and balancing agency.
 - 1. Project number.
 - 2. Contract number.
 - 3. Project title.
 - 4. Project location.
 - 5. Project architect.
 - 6. Project mechanical engineer.
 - 7. Test and balance agency.
 - 8. Balancing Engineer.
 - 9. Construction Manager.
 - 10. Mechanical Contractor.
 - 11. Date tests were performed.
 - 12. Certification.
- D. The test and balance report shall be recorded on report forms conforming to the recommended forms in AABC National Standards. At a minimum, the report shall include:
 - 1. Preface: A general discussion of the system, any abnormalities and problems encountered.
 - 2. Instrumentation List: The list of instruments including type, model, manufacturer, serial number, and calibration dates.
 - 3. System Identification: In each report the supply, return and exhaust openings and traverse points shall be numbered and/or lettered to correspond to the numbers and letters used on the report data sheets.

4. Air Handling Equipment (Makeup Air, Roof Top Units, etc.)
 - a. Manufacturer, model number, and serial number.
 - b. All design and manufacturer related data.
 - c. Total actual CFM by traverse if practical; if not practical, the sum of the outlets may be used, or a combination of each of these procedures. For specific systems, such as ones with diversity, see the AABC National Standards.
 - d. Suction and discharge static pressure of each fan, as applicable.
 - e. Outside air and return air total CFM.
 - f. Actual operating current, voltage, and brake horsepower of each fan motor.
 - g. Final RPM of each fan.
 - h. Fan and motor sheave manufacturer, model, size, number of grooves, and center distance.
 - i. Belt size and quantity.
 - j. Static pressure controls final operating setpoints.

5. Pumps
 - a. Manufacturer, size, and serial number.
 - b. All design and manufacturer's related data.
 - c. Pump operating suction and discharge pressure and final total dynamic head.
 - d. No flow (pump discharge valve closed) suction and discharge pressure and corresponding total dynamic head. This procedure is to determine actual impeller size.
 - e. Rated and actual operating current, voltage, and brake horsepower of each pump motor.
 - f. Submit pump curve showing design, operating, and no-flow points of operation.

6. Boilers
 - a. Manufacturer, model number, and serial number.
 - b. All design and manufacturer's rated data.
 - c. Rated and actual pressure drop across boilers and related GPM.
 - d. Entering and leaving water temperatures.

7. Heat Exchangers
 - a. Manufacturer and model number.
 - b. All design and manufacturer's related data.
 - c. Service and location.
 - d. Actual pressure drop and related GPM.
 - e. Entering and leaving water temperatures.
 - f. Temperature control setting.

8. Electric Heating
 - a. Manufacturer and model number.
 - b. All design and manufacturer rated data.
 - c. Actual operating current and voltage.
 - d. Coil location and identification number.

9. Cooling Tower
 - a. A copy of the Cooling Tower Test Data Summary sheet.
 - b. A sketch of the cooling tower installation showing tower orientation, principal dimensions, location of temperature and flow rate measurement points, and notation of any building obstructions or other equipment in the immediate vicinity of the tower.
 - c. Copies of completed test data sheets.
 - d. A copy of test calculations, including performance curves and cross plots.
 - e. Observations on compliance with test code limitations and uniformity of test conditions. Include comments on any suggested changes to the tower such as increasing fan speed or blade pitch to obtain rated brake horsepower.

END OF SECTION