SECTION 230593 – TESTING, ADJUSTING, AND BALANCING HVAC SYSTEMS

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(Engineer shall edit specifications and blue text in header to meet project requirements. This includes but is not limited to updating Equipment and/or Material Model Numbers indicated in the specifications and adding any additional specifications that may be required by the project. Also turn off "Underlines".)

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this section and all other sections of Division 23.

1.2 SUMMARY

A. This section includes the requirements for testing, adjusting and balancing the following systems: <Coordinate with UMB and edit for project>

1. Balancing Air Systems:

   a. Supply air distribution systems.
   b. Exhaust air distribution systems.
   c. Supply and exhaust air devices.
   d. Energy recovery air side systems.

2. Balancing Hydronic Piping Systems:

   a. Primary heating & cooling hydronic systems.
   b. Secondary heating and cooling hydronic systems.
   c. Energy recovery hydronic systems.

3. Balancing steam systems.

4. Testing, Adjusting, and Balancing Equipment:

   a. Heat exchangers.
   b. Pumps.
   c. Chillers.
   d. Cooling towers.
   e. Water cooled condensing units.
   f. Air handling units.
   g. Heat transfer coils.
   h. Supply and exhaust terminal units.
   i. Fan coil units, cabinet heaters, unit heaters.
   j. Perimeter heating system.
   k. Exhaust/Relief/Return air fans.

5. Testing, adjusting, and balancing existing systems and equipment:

   a. Limited to renovation projects. See drawings for locations of existing HVAC equipment.

1.3 PREINSTALLATION MEETINGS <Coordinate with UMB. Delete if not required for Project>

A. TAB Conference: Conduct a TAB conference at Project site after approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Provide a minimum of fourteen (14) days' advance notice of scheduled meeting time and location.

1. Minimum Agenda Items:

   a. The Contract Documents examination report.
   b. The TAB plan.
   c. Needs for coordination and cooperation of trades and subcontractors.
   d. Proposed procedures for documentation and communication flow.

1.4 ACTION SUBMITTALS

A. Agency Data: within thirty (30) days of award of contract submit proof that proposed testing, adjusting, and balancing agency meets the qualifications specified.

B. LEED Submittals: <Delete if not LEED Project>

1. Air Balance Report for Prerequisite IEQ 1: Documentation indicating that work complies with ASHRAE 62.1, Section 7.2.2 - "Air Balancing."
2. TAB Report for Prerequisite EA 2: Documentation indicating that work complies with ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: Within thirty (30) days of Contractor's Notice to Proceed, submit documentation that the TAB specialist and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.

B. Contract Documents Examination Report: Within ninety (90) days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.

C. Strategies and Procedures Plan: Within sixty (60) days of Contractor's Notice to Proceed, submit TAB strategies and step by step procedures as specified in "Preparation" Article.

D. System Readiness Checklists: Within ninety (90) days of Contractor's Notice to Proceed, submit system readiness checklists as specified in "Preparation" Article.

E. Examination Report: Submit a summary report of the examination review required in "Examination" Article.

F. Final TAB Report Submittal: Within thirty (30) days after all fieldwork has been completed, submit a final TAB report as detailed in Part 3 of this Section to assure design objectives are met and to assist Owner in future maintenance.

1.6 CLOSEOUT SUBMITTAL

A. Operation and Maintenance Data: Include a copy of the final approved TAB Report in the operation and maintenance manuals.

1.7 QUALITY ASSURANCE

A. General: Employ services of an independent testing, adjusting, and balancing agency to be the single source of responsibility to test, adjust, and balance the HVAC systems indicated on the drawings serving the project area. Services shall include checking installations for conformity to design, measurement and establishment of fluid quantities of mechanical systems as required to meet the requirements of the design documents, and record and report the results.

B. Certification: Certified by Associated Air Balance Council (AABC) in those testing and balancing disciplines required for this project, and having at least one (1) Professional Engineer registered in State in which services are to be performed, certified by AABC as Test and Balance Engineer. NEBB certified balancing companies will not be permitted.

C. TAB Specialists Qualifications: Certified by AABC.

1. TAB Field Supervisor: Employee of the TAB specialist and certified by AABC.
2. TAB Technician: Employee of the TAB specialist and certified by AABC as a TAB technician.

D. Instrumentation Type, Quantity, Accuracy, and Calibration: Comply with requirements in ASHRAE 111, Section 4, "Instrumentation."

E. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."

F. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

G. Work shall be accomplished in accordance with specifications. Procedures specified shall be followed and, if not specifically described herein, in general, shall be in accordance with Associated Air Balance Council's National Standards.

H. Design Review: Review all design drawings and specifications.

1. Review shall include:

   a. Duct pressure classification.
   b. Control device location and balancing devices location in duct systems and piping systems.
   c. Indicate additional balancing devices required for proper balancing.
   d. Specifications on all devices required for balancing.
   e. Note any potential noise problems.

2. Within ninety (90) days of award of contract, meet with the CM, Owner, A/E, Mechanical Contractor, and Building Automation System Contractor to review procedures and agenda and comments on design documents as to potential problem areas.

I. Shop Drawing Review: Review the Building Automation System (BAS) shop drawing submittals noting any potential balancing problems. Note comments on submittal, sign, stamp and return to General Contractor. All BAS submittals must be reviewed by balancing agency prior to review by the engineer.

J. Pre Balancing Conference: Prior to beginning of testing, adjusting, and balancing procedures, schedule and conduct conference with the CM, Owner, and representatives of installers of mechanical systems. Objective of conference is final coordination and verification of system operation and readiness for testing, adjusting, and balancing.

K. During construction, balancing agency shall inspect the installation of pipe systems, sheet metal work, temperature controls, and other component parts of heating, ventilating, and air conditioning systems. Inspections shall be performed periodically as work progresses. Minimum of two (2) inspections are required as follows:

1. One (1) when 60% of ductwork is installed;
2. Two (2) when 90% of equipment is installed.
3. Balancing agency shall submit brief written report of each inspection to Owner and engineer.

1.8 STANDARDS

A. Associated Air Balance Council (AABC) Publication: National Standards for Testing and Balancing Heating, Ventilating and Air Conditioning Systems, Latest Edition.

B. American Society of Heating, Refrigeration and air Conditioning Engineers (ASHRAE) Publications:

1. "ASHRAE Research Report No. 1162, "Air Flow Measurements at Intake and Discharge Openings and Grilles," ASHVE Transactions, Volume 46.

2. ASHRAE Handbook of Fundamentals, Latest Edition.

C. American National Standards Institute (ANSI) Publications:

1. ANSI/AIHA Z9.5 American National Standard for Laboratory Ventilation, Latest Edition.
2. S1.4 General - Purpose Sound Level Meters, Specifications for,

D. Sheet Metal and Air Conditioning Contractors National Association Inc. (SMACNA) - Air Duct Leakage Test Manual, Latest Edition.

E. Scientific Equipment & Furniture Association (SEFA) Standard SEFA1-1992 Laboratory Fume Hoods.

1.9 FIELD CONDITIONS <Edit for particular Project>

A. New Construction Project: University personnel will occupy the new building beginning from the projects date of substantial completion. All TAB operations shall be completed prior to the date of substantial completion.

B. Renovation Projects: During the renovation to the project area, adjacent areas of the building outside of the project area are occupied by University personnel. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

1.10 WARRANTY/GUARANTEE

A. See Division 23 Specification Section "Basic Mechanical Requirements – HVAC" for warranty and guarantee requirements.

PART 2 - PRODUCTS

2.1 INSTRUMENTATION

A. Provide all required instrumentation to obtain proper measurements. Application of instruments and accuracy of instruments and measurements shall be in accordance with requirements of AABC.

B. Instruments used for measurements shall be accurate, and calibration histories for each instrument to be available for examination by A/E upon request. Calibration and maintenance of instruments shall be in accordance with requirements of AABC.

2.2 INSTRUMENT TEST HOLE PLUGS

A. Center-pull plugs similar to Alliance Plastics CP Series. Plug material shall be Grade 1 virgin polyethylene.

B. Do not drill test holes in welded ducts serving containment areas.

2.3 FUME HOOD TESTING AND MEASUREMENT EQUIPMENT

A. Anemometers:

1. Accuracy: +/-5% of reading
2. Internal Time Constant (ITC): Less than or equal to 100 ms
3. Definitions:

a. ITC is the amount of time it takes the sensor to respond 63% of the way to a step change.
b. Response time is the length of time to get to within the stated accuracy of the sensor.
c. Response time = ITC * three (3) or five (5) depending on the accuracy.

B. Tracer gas ejector in accordance with ANSI/ASHRAE 110.

C. Tracer Gas (SF6) Sensor:

1. Sensitivity: 0.01 to 100 ppm
2. Accuracy:
3. Above 0.1 ppm: +/-10% of reading.
4. At or below 0.1 ppm: +/-25% of reading.

D. Data Acquisition System: Minimum six channel system capable of simultaneous sampling of 10Hz or greater.

PART 3 - EXECUTION

3.1 GENERAL PROCEDURES

A. General: Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Total System Balance" and in this Section to obtain air and water quantities indicated and required for proper operation of the systems.

B. System Operation: During all tests, it shall be demonstrated that all systems shall be free from leaks and all parts of each system are operating correctly. If not, report deficiencies to the CM/GC and the UMB – PM. Balancing Firm shall make final adjustments to equipment as may be required for proper operation, maintaining correct temperatures in all parts of the building. Controls shall be adjusted by BAS technicians in conjunction with Balancing Firm. Coordinate set points and adjustments with BAS.

C. Hydronic Systems: Balance each hydronic circulation system installed under this contract to achieve water quantities, pressure and temperature drops in all equipment and parts of system as indicated on the plans, in specifications, and on the approved shop drawings.

D. Air Systems: Balance each air circulation system, installed under this contract to achieve air quantities, pressure and temperature drops and static pressures in all equipment and parts of system as indicated on the plans, in specifications, and on the approved shop drawings.

E. Noise: Study and report on excessive noise conditions which may develop during system balancing. Report shall be sent to CM and UMB – PM in a form of a "pdf" file.

F. TAB Field Markings: Field mark equipment and balancing devices, including damper control positions, valve position indicators, fan speed control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.

G. Traverse Test Probes: Where insulation on ductwork and/or plenums needs to be removed to perform traverse measurements cut and remove insulation as necessary to complete the TAB work. When the work has been completed plug each opening with a properly sized rubber grommet to seal the holes air tight. Coordinate with the mechanical contractor to have the duct insulation repaired to match its previous condition.

H. Acceptable System Tolerance: Unless otherwise specified, the maximum acceptable tolerances for the air and water flow rates shall be +/- 10% of the flow rates as indicated on the drawings and approved submittals.

3.2 TAB REPORT

A. TAB Report: The TAB report shall include the following:

1. Certification form signed and dated by a TAB professional engineer who represents the TAB Company.
2. Table of contents with separate sections for air system balance and hydronic system balance.
3. List of abbreviations used in the report.
4. List of instruments used with instrument type, manufacturer, serial number, range, and calibration date.
5. Job notes.
6. Completed TAB Data Forms as specified.

B. Units of Measurement: Units of measurements shall be in inch/pound (IP) units.

C. Equipment Labels: Includes all major equipment and devices in each system. Include the following:

1. Equipment tag from the drawings.

2. Equipment name.
3. Manufacturer.
4. Model number.
5. Serial number.
6. Location.

D. TAB Data Forms: For each component that requires a TAB procedure provide a TAB data form with the design data from the construction documents and/or approved submittals and the actual measured data that represents the operation of each system and components as follows:

1. Hydronic Systems and Equipment: Chillers, cooling towers, AHU coils, energy recovery coils, pumps and terminal unit coils:

   a. Total water flow rate in GPM.
   b. Water side pressure drop in feet (ft.).
   c. Water temperature entering in °F.
   d. Water temperature leaving in °F.
   e. Water side temperature difference in °F between EWT/LWT.

2. Air Systems and Equipment: Air handling units, energy recovery units and fans:

   a. Total air volume in CFM.
   b. Return air volume in CFM.
   c. Outside air volume in CFM.
   d. Static pressure (TSP/ESP) in inches wg.
   e. Suction pressure in inches wg.
   f. Discharge pressure in inches wg.
   g. Air side pressure drop in inches water gauge (wg).
   h. Air temperature entering in °F.
   i. Air temperature leaving in °F.
   j. Air side temperature difference in °F between EAT/LAT.
   k. Damper positions % open/closed.

3. Motors: For fans and pumps:

   a. Motor HP.
   b. Motor BHP.
   c. Motor volts and phase.
   d. Motor amps.
   e. Motor RPM.
   f. Fan RPM.
   g. Fan sheave.
   h. Motor sheave.
   i. Belts.
   j. Motor efficiency.

4. Air Devices: Diffusers and grilles:

   a. Outlet number.
   b. Outlet size
   c. Outlet type.
   d. Min/max air volume in CFM.

5. Terminal Units: Include supply and exhaust terminal units, fan coil units, cabinet heaters, unit heaters:

   a. Outlet number.
   b. Min/max air volume in CFM.
   c. Velocity pressure at minimum.
   d. Velocity pressure at maximum.
   e. DDC set point value.
   f. Damper position % open/closed.

6. Duct Traverses:

   a. Duct height in inches.
   b. Duct width in inches.
   c. Duct area in square feet.
   d. Average velocity in FPM.
   e. Design air volume in CFM.
   f. Actual air volume in CFM.
   g. Duct S.P. in inches wg.
   h. Measured velocity table with appropriate traverse points and velocity readings for indicated duct size.

E. Instrument Calibration Reports: Instrument calibration reports shall include the following data:

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

3.3 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems designs that may preclude proper TAB of systems and equipment.

B. Examine installed systems for balancing devices, such as test ports, gage cocks, thermometer wells, flow control devices, balancing valves and fittings, and manual

volume dampers. Verify that locations of these balancing devices are applicable for intended purpose and are accessible.

C. Examine the approved submittals for HVAC systems and equipment.

D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems output, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine ceiling plenums and/or underfloor air plenums used for supply, return, or relief air to verify that they are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire stopped if required.

F. Examine equipment performance data including fan and pump curves. <Edit for particular Project>

1. 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.
2. Calculate system effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.

G. Examine system and equipment installations and verify that field quality control testing, cleaning, and adjusting specified in individual Sections have been performed.

H. Examine test reports specified in individual system and equipment Sections.

I. Examine HVAC equipment and verify that bearings are greased, belts are aligned and tight, filters are clean, and equipment with functioning controls is ready for operation.

J. Examine terminal units such as CV/VAV supply boxes, CV/VAV exhaust boxes (general exhaust & fume hoods), fan coil units, unit heaters, cabinet heaters, compressorized cooling units and verify that they are accessible and their controls are connected and functioning.

K. Examine strainers. Verify that startup screens have been replaced by permanent screens with indicated perforations.

L. Examine control valves for proper installation for their intended function of throttling, diverting, or mixing fluid flows.

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

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

O. Examine operating safety interlocks and controls on HVAC equipment.

P. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.4 PREPARATION

A. Perform system readiness checks of HVAC systems and equipment to verify system readiness for TAB work. Include, at a minimum, the following:

1. Air Side:

a. Verify that leakage and pressure tests on air distribution systems have been satisfactorily completed.
b. Duct systems are complete with terminals installed.
c. Volume, smoke, and fire dampers are open and functional.
d. Clean filters are installed.
e. Fans are operating, free of vibration, and rotating in correct direction.
f. Variable frequency controllers' startup is complete and safeties are verified.
g. Automatic temperature control systems are operational.
h. Ceilings are installed.
i. Windows and doors are installed.
j. Suitable access to balancing devices and equipment is provided.

2. Water Side:

a. Verify leakage and pressure tests on water distribution systems have been satisfactorily completed.
b. Piping is complete with terminals installed.
c. Water treatment is complete.
d. Systems are flushed, filled, and air purged.
e. Strainers are pulled and cleaned.
f. Control valves are functioning per the sequence of operation.
g. Shutoff and balance valves have been verified to be 100% open.
h. Pumps are started and proper rotation is verified.
i. Pump gage connections are installed directly at pump inlet and outlet flanges or in discharge and suction pipe prior to valves or strainers.

j. Variable frequency controllers' startup is complete and safeties are verified.
k. Suitable access to balancing devices and equipment is provided.

3.5 PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain approved submittals and manufacturer's outlet factors and recommended testing procedures. Cross check the summation of required outlet volumes with required fan design flow rates.

B. In conjunction with the BAS, fans and equipment shall be started and operated per design/approved sequence of operation.

C. With the supply and exhaust fans set for the respective design air flow volumes, system static pressures, fan rpm, motor rpm and power, and with system dampers set to handle normal minimum outdoor air perform and record the following test:

1. Air Handling Equipment:

a. Test for Total Air

1) Sum of discharge, exhaust air, return air and outside air ducts.
2) Number and locations of velocity readings taken.
3) Duct average velocity.
4) Total airflow.

b. After completion of tests, adjustments, and balancing under minimum outdoor air conditions, set system for 100% outdoor air. Repeat the total airflow tests to check field versus design conditions. Result's under the outdoor air cycle shall agree with conditions found under "minimum fresh air operation" before system is considered to be in balance. Adjustments of proper dampers shall be made to achieve balance.

c. If airflow is not within 10% of design capacity at rated speed, review system conditions, procedures, and recorded data. Check and record pressure drops across filters, compensate for clean versus dirty filters, coils, sound traps, airflow sensors, etc., to indicate excessive pressure loss or leakage. Resolve problems with appropriate contractor. If systems are properly operating, and airflow is still unacceptable, adjust fan drive in accordance with manufacturer's recommendations to obtain proper airflow and static pressure. Systems shall be balanced and operated at lowest feasible static pressure with allowance for filter loading. Record fan suction pressure, fan discharge pressure, amperage and airflow measurement. Correct fan curves to indicate new points of balance. Fan motor shall not be overloaded.

2. Air Duct Mains and Branches:

   a. Design and actual airflow.
   b. Adjust, measure and record airflow, static pressure of duct mains and branch ducts to provide required pressure and airflow at terminal devices.

3. Terminal Units:

   a. Design and actual airflow.
   b. Adjust minimum or maximum setting of each terminal unit as required to obtain required airflow of outlets in accordance with manufacturer's procedures and recommendations.
   c. In conjunction with the BAS, operate controls, i.e., thermostats, switches and pressure controls in accordance with design sequence to verify proper operation.
   d. Report control problems in writing to the Contractor. Resolve sequence problems with the BAS, with the Contractor and Architect at no additional cost.

4. Air Outlets (supply, return and exhaust registers diffusers and grilles):

   a. Design and actual airflow.
   b. Adjust outlets to obtain design airflow within ±5%.
   c. Adjust direction of throw as required to match final installation location to prevent drafts.
   d. With supply, return and exhaust balanced to design airflow, report room pressurization, (positive or negative). Record pressure readings relative to adjacent spaces and submit them to the Owner and Architect.

5. Fume Hoods and Biosafety Cabinets: <Edit/Delete as required for Project>

   a. Perform fume hood testing and performance verification for all hoods and biosafety cabinets as described in SEFA 1-1992 "Fume Hood Evaluation in the Field" and in accordance with ASHRAE 110 - Velocity test.
   b. Tests shall be performed in conjunction with other balancing for laboratories have been completed.
   c. Work with the Contractor and Installers to remedy deficiencies. Retest as required until hoods are performing properly. If required, readjust supply and exhaust minimum and maximum airflows to achieve specified face velocities.
   d. Provide field tag for each hood indicating that its performance has been field-verified (format as per Owner's standard).
   e. Coordinate with the BAS and provide him with data in order to calibrate fume hood and biosafety cabinet face velocity monitors.

f. Some of fume hoods and biosafety cabinets shown on drawings may be installed after completion of contract, and ceiling exhaust grille will be connected to exhaust duct in lieu of connecting exhaust duct to hood (or cabinet). Perform testing and balancing for laboratories where hoods are replaced to obtain same airflows and sequences of operation as required when hood (or cabinet) is present.

6. Laboratory Pressurization: <Edit/Delete as required for Project>

a. Supply and exhaust valves:

1) Verify supply and general exhaust valve maximum and minimum air quantities via flow hood readings at outlets/inlets.
2) Verify fume hood exhaust valves for maximum and minimum air quantities via duct traverse.

b. Perform fume hood testing as specified above.
c. Readjust supply/exhaust maximum and minimum air quantities to achieve specified face velocities at hoods.
d. Using smoke stick, verify room pressurization for each lab through entire range of volume tracking control. In conjunction with the BAS adjust supply and exhaust air quantities to maintain desired direction of airflow over entire control range.

D. Sheaves and Belts: Should the air balance fall short of or exceed the specified tolerances, change and replace sheaves and belts to achieve the acceptable air balance. Replacement of sheaves and belts shall be provided at no additional cost.

E. Verify that air duct system is sealed as specified. Balancing contractor shall witness leakage tests required of sheet metal construction.

F. Balancing contractor shall witness leakage tests required of sheet metal contractor.

3.6 PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports for each system pump, and equipment. Obtain approved submittals and manufacturer recommended testing procedures. Cross check the summation of required coil and equipment flow rates with each system pump design flow rate.

B. In conjunction with the BAS, pumps and equipment shall be started and operated per design/approved sequence of operation.

C. With manual valves open, and control valves in normal position, adjust discharge balancing valve to obtain design flow. Compare data with pump submittal curve. If test point falls on curve, proceed with balancing. If recorded data does not fall on pump curve, plot new curve parallel with other curves on chart, from zero to maximum flow.

Open discharge balancing valve to full and record discharge pressure, suction pressure and total head. Readjust balancing valve to obtain suction and discharge design flow and pressure, and record data. Check and record pump motor voltage and amperage. Pump motor shall not be overloaded.

D. With pump system adjusted, perform following tests, compile data and submit report:

1. Pumps:

a. Design Data:

1) Flow and total dynamic head.
2) Pump speed, and motor output.

b. Installed equipment:

1) Manufacturer, size and model number.
2) Type drive.
3) Motor rating, voltage, and phase.
4) Full load amperes.

c. Field Test:
1) Discharge pressures: Full flow and zero flow.
2) Suction pressures: Full flow and zero flow.
3) Operating flow and total dynamic head
4) No load amperes (where possible.)
5) Full flow amperes, zero flow amperes.
6) Calculated motor output.

E. With pump system properly adjusted, proceed with following tests adjustments and compilation of data:

1. Pipe Mains and Branches:

a. Adjust branch balancing valves to obtain pressure and flowrates required for terminal devices, i.e., coil, radiation, etc.
b. Provide the following:

1) Manufacturer's model number, size of heat exchanger, number of passes.
2) Design and actual flow rate and pressure drop.
3) Record entering and leaving water temperatures.
4) In conjunction with the BAS adjust steam control valve as required to obtain design temperatures at design flowrate.

c. Terminal Devices:

1) Manufacturer's model number, type of terminal device and rated heat output.
2) Flowrate and differential pressure through component including control device.
3) Adjust balancing device to obtain required flowrate through device, in accordance with manufacturer's procedures and recommendations.
4) Record the temperature of the fluid at inlet and outlet of device. Record the temperature of the air entering and leaving the coils. Compare data with design performance, if data is not in conformance with approved shop drawings or design intent, readjust water system to obtain acceptable performance.
5) With air and water system balanced and in conjunction with "BAS" operate controls, i.e., thermostats, switches, etc., in accordance with design sequence to verify proper operation.
6) Report control problems in writing to General Contractor. Resolve sequence problems with the BAS, the Contractor and Architect at no additional cost.

d. Heat transfer equipment including steam, hot water, chilled water, glycol water, coils, etc. <Edit list for particular Project>

1) Measured Parameters:

a) Flowrate.
b) Heat transfer.
c) Entering and leaving temperatures.
d) Pressure drops.
e) Ambient dry and wet bulb (for cooling towers).

2) Equipment data:

a) Manufacturer and model number.
b) Motor output horse powers.
c) Serial numbers.

3) Design Data:

a) Include design data in submittal for comparison.

e. Environmental Rooms <Edit for particular Project>

1) Measured Parameters:

a) Flowrate to each condensing unit. Set balance valves to obtain rated flow based on 85ºF entering temperature for all units simultaneously.

F. Check and Verify: Check and verify the following system requirements have been completed and are in proper working order:

1. Check liquid level in expansion tank.
2. Check highest vent for adequate pressure.
3. Check flow control valves for proper position.
4. Locate start/stop and disconnect switches, electrical interlocks, and motor starters.
5. Verify that motor starters are equipped with properly sized thermal protection.
6. Check that air has been purged from the system.

3.7 PROCEDURES FOR PRIMARY/ SECONDARY HYDRONIC SYSTEMS

A. Balance the primary circuit flow first.

B. Balance the secondary circuits after the primary circuits are complete.

C. 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 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.

D. Adjust flow measuring devices installed in mains and branches to design water flows.
   1. Measure flow in main and branch pipes.
   2. Adjust main and branch balance valves for design flow.
   3. Remeasure each main and branch after all have been adjusted.

E. Adjust flow measuring devices installed at terminals for each space to design water flows.

   1. Measure flow at terminals.
   2. Adjust each terminal to design flow.
   3. Remeasure 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.

F. For systems with pressure independent valves at terminals:

   1. Measure differential pressure and verify that it is within manufacturer's specified range.
   2. Perform temperature tests after flows have been verified.

G. For systems without pressure independent valves or flow measuring devices at terminals:

   1. Measure and balance coils by either coil pressure drop or temperature method.
   2. If balanced by coil pressure drop, perform temperature tests after flows have been verified.

H. Verify final system conditions as follows:

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

I. Verify that memory stops have been set.

3.8 PROCEDURES FOR STEAM SYSTEMS

A. Record upstream and downstream pressure of each piece of equipment.

B. Record upstream and downstream steam pressure setting of pressure reducing valves and the steam flow in Lbs/Hr.

C. Record the steam pressure setting of pressure relief valve.

D. Check settings and operation of automatic temperature control valves, and pressure reducing valves. Record final settings.

E. Check settings and operation of each safety valve. Record settings.

F. Steam Traps: Verify the operation of each steam trap. Test any steam traps suspected of malfunctioning, using a pyrometer. Report the deficiencies in writing to the Contractor.

3.9 PROCEDURES FOR HEAT EXCHANGERS

A. With steam systems properly adjusted for design pressure, proceed with following test, adjustments and compilation of data:

1. Design Data:

   a. Manufacturer's model number, type of equipment and rated heat transfer.

2. Record steam pressure.
3. Check operation of steam traps and air vents or vacuum breakers.
4. Record temperatures of fluids entering and leaving.
5. Adjust control valve to obtain design performance.
6. In conjunction the BAS, operate controls, i.e., thermostats, control devices in accordance with design sequence to verify proper operation.
7. Report control problems in writing to the BAS and the Contractor. Resolve sequence problems with the BAS, the Contractor and Architect at no additional cost.

3.10 PROCEDURES FOR MOTORS

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

1. Manufacturer's name, model number, and serial number.
2. Motor horsepower rating.
3. Motor rpm.
4. Phase and hertz.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter size and thermal protection element rating.
8. Service factor and frame size.

B. Motors Driven by Variable Frequency Controllers: Test manual bypass of controller to prove proper operation.

3.11 PROCEDURES FOR CHILLERS

A. Balance water flow through each evaporator and condenser to within specified tolerances of indicated flow with all pumps operating. With only one chiller operating in a multiple chiller installation, do not exceed the flow for the maximum tube velocity recommended

by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:

1. Evaporator water entering and leaving temperatures, pressure drop, and water flow.
2. For water cooled chillers, condenser water entering and leaving temperatures, pressure drop, and water flow.
3. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
4. Power factor if factory installed instrumentation is furnished for measuring kilowatts.
5. Kilowatt input if factory installed instrumentation is furnished for measuring kilowatts.
6. Capacity: Calculate in tons of cooling.
7. For air cooled chillers, verify condenser fan rotation and record fan and motor data including number of fans and entering and leaving air temperatures.

3.12 PROCEDURES FOR COOLING TOWERS

A. Balance total condenser water flows to towers. Measure and record the following data:

1. Condenser water flow to each cell of the cooling tower.
2. Entering and leaving water temperatures.
3. Wet and dry bulb temperatures of entering air.
4. Wet and dry bulb temperatures of leaving air.
5. Condenser water flow rate recirculating through the cooling tower.
6. Cooling tower spray pump discharge pressure.
7. Condenser water flow through bypass.
8. Fan and motor operating data.

3.13 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering and leaving air temperatures.

C. Record fan and motor operating data.

3.14 PROCEDURES FOR HEAT TRANSFER COILS

A. Measure, adjust, and record the following data for each water coil:

1. Entering and leaving water temperature.
2. Water flow rate.
3. Water pressure drop for major (more than 20 gpm) equipment coils, excluding unitary equipment such as reheat coils, unit heaters, and fan-coil units.

4. Dry bulb temperature of entering and leaving air.
5. Wet bulb temperature of entering and leaving air for cooling coils.
6. Airflow.

B. Measure, adjust, and record the following data for each electric heating 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.
5. Calculated kilowatt at full load.
6. Fuse or circuit breaker rating for overload protection.

C. Measure, adjust, and record the following data for each steam coil:

1. Dry bulb temperature of entering and leaving air.
2. Airflow.
3. Inlet steam pressure.

D. Measure, adjust, and record the following data for each refrigerant coil:

1. Dry bulb temperature of entering and leaving air.
2. Wet bulb temperature of entering and leaving air.
3. Airflow.

3.15 SOUND TESTS <Delete if not required>

A. After the systems are balanced and construction is Substantially Complete, measure and record sound levels at five (5) locations as designated by the Architect.

B. Instrumentation:

1. The sound testing meter shall be a portable, general purpose testing meter consisting of a microphone, processing unit, and readout.
2. The sound testing meter shall be capable of showing fluctuations at minimum and maximum levels, and measuring the equivalent continuous sound pressure level (LEQ).
3. The sound testing meter must be capable of using 1/3 octave band filters to measure mid frequencies from 31.5 Hz to 8000 Hz.
4. The accuracy of the sound testing meter shall be plus or minus one (1) decibel.

C. Test Procedures:

1. Perform test at quietest background noise period. Note cause of unpreventable sound that affects test outcome.
2. Equipment should be operating at design values.

3. Calibrate the sound testing meter prior to taking measurements.
4. Use a microphone suitable for the type of noise levels measured that is compatible with meter. Provide a windshield for outside or in duct measurements.
5. Record a set of background measurements in dBA and sound pressure levels in the eight unweighted octave bands 63 Hz to 8000 Hz (NC) with the equipment off.
6. Take sound readings in dBA and sound pressure levels in the eight un weighted octave bands <63 Hz to 8000 Hz (NC)> <31.5 Hz to 4000 Hz (RC)> with the equipment operating.
7. Take readings no closer than thirty six (36) inches from a wall or from the operating equipment and approximately sixty (60) inches from the floor, with the meter held or mounted on a tripod.
8. For outdoor measurements, move sound-testing meter slowly and scan area that has the most exposure to noise source being tested. Use 'A' weighted scale for this type of reading.

D. Reporting:

1. Report shall record the following:

   a. Location.
   b. System tested.
   c. dBA reading.
   d. Sound pressure level in each octave band with equipment on and off.

2. Plot sound pressure levels on <NC> <RC> worksheet with equipment on and off.

3.16 VIBRATION TESTS

A. After systems are balanced and construction is Substantially Complete, measure and record vibration levels on equipment having motor horsepower equal to or greater than <ten (10)> <fifteen (15)> <twenty five (25)> <Insert number>.

B. Instrumentation:

1. Use portable, battery operated, and microprocessor controlled vibration meter with or without a built in printer.
2. The meter shall automatically identify engineering units, filter bandwidth, amplitude, and frequency scale values.
3. The meter shall be able to measure machine vibration displacement in mils of deflection, velocity in inches per second, and acceleration in inches per second squared.
4. Verify calibration date is current for vibration meter before taking readings.

C. Test Procedures:

1. To ensure accurate readings, verify that accelerometer has a clean, flat surface and is mounted properly.
2. With the unit running, set up vibration meter in a safe, secure location. Connect transducer to meter with proper cables. Hold magnetic tip of transducer on top of the bearing, and measure unit in mils of deflection. Record measurement, then move transducer to the side of the bearing and record in mils of deflection. Record an axial reading in mils of deflection by holding nonmagnetic, pointed transducer tip on end of shaft.
3. Change vibration meter to velocity (inches per second) measurements. Repeat and record above measurements.
4. Record CPM or rpm.
5. Read each bearing on motor, fan, and pump as required. Track and record vibration levels from rotating component through casing to base.

D. Reporting:

1. Report shall record location and the system tested.
2. Include horizontal vertical axial measurements for tests.
3. Verify that vibration limits follow Specifications, or, if not specified, follow the General Machinery Vibration Severity Chart or Vibration Acceleration General Severity Chart from the AABC National Standards. Acceptable levels of vibration are normally "smooth" to "good."
4. Include in report General Machinery Vibration Severity Chart, with conditions plotted.

3.17 DUCT LEAKAGE TESTS

A. Witness the duct pressure testing performed by Installer.

B. Verify that proper test methods are used and that leakage rates are within specified tolerances.

C. Report deficiencies observed.

3.18 CONTROLS VERIFICATION

A. In conjunction with system balancing, perform the following:

1. Verify temperature control system is operating within the design limitations.
2. Confirm that the sequences of operation are in compliance with Contract Documents.
3. Verify that controllers are calibrated and function as intended.
4. Verify that controller set points are as indicated.
5. Verify the operation of lockout or interlock systems.
6. Verify the operation of valve and damper actuators.

7. Verify that controlled devices are properly installed and connected to correct controller.
8. Verify that controlled devices travel freely and are in position indicated by controller: open, closed, or modulating.
9. Verify location and installation of sensors to ensure that they sense only intended temperature, humidity, or pressure.

B. Reporting: Include a summary of verifications performed, remaining deficiencies, and variations from indicated conditions.

3.19 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

A. Perform a preconstruction inspection of existing equipment that is to remain and be reused.

1. Measure and record the operating speed, airflow, and static pressure of each fan.
2. Measure motor voltage and amperage. Compare the values to motor nameplate information.
3. Check the refrigerant charge.
4. Check the condition of filters.
5. Check the condition of coils.
6. Check the operation of the drain pan and condensate-drain trap.
7. Check bearings and other lubricated parts for proper lubrication.
8. Report on the operating condition of the equipment and the results of the measurements taken. Report deficiencies.

B. Before performing testing and balancing of existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished. Verify the following:

1. New filters are installed.
2. Coils are clean and fins combed.
3. Drain pans are clean.
4. Fans are clean.
5. Bearings and other parts are properly lubricated.
6. Deficiencies noted in the preconstruction report are corrected.

C. Perform testing and balancing of existing systems to the extent that existing systems are affected by the renovation work.

1. Compare the indicated airflow of the renovated work to the measured fan airflows, and determine the new fan speed and the face velocity of filters and coils.

2. Verify that the indicated airflows of the renovated work result in filter and coil face velocities and fan speeds that are within the acceptable limits defined by equipment manufacturer.
3. If calculations increase or decrease the airflow rates and water flow rates by more than 5%, make equipment adjustments to achieve the calculated rates. If increase or decrease is 5% or less, equipment adjustments are not required.
4. Balance each air outlet.

3.20 TOLERANCES

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

1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus or minus 10%.
2. Air Outlets and Inlets: Plus or minus 10%.
3. Heating Water Flow Rate: Plus or minus 10%.
4. Cooling Water Flow Rate: Plus or minus 10%.

B. Maintaining pressure relationships as designed shall have priority over the tolerances specified above.

3.21 PROGRESS REPORTING

A. Initial Construction Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems balancing devices. Recommend changes and additions to systems balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Status Reports: Prepare weekly progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.22 FINAL TAB REPORT

A. Final TAB Report: The final TAB report shall be a complete record of the HVAC system performance, including conditions of operation, items outstanding, and any deviations found during the TAB process and serve as a reference of the actual operating conditions of the systems. All measurements and test results that appear in the TAB report must be made on site and dated by the AABC technicians and/or TAB engineer performing the work. This report shall be provided as a complete electronic “pdf” file organized as specified and submitted to the A/E for review.

B. Sign & Seal: Final TAB report shall bear the seal and signature of Test and Balance Engineer. TAB Report shall be certified proof that systems have been tested, adjusted,

and balanced in accordance with referenced standards; are an accurate representation of how systems have been installed; are true representation of how systems are operating at completion of testing, adjusting, and balancing procedures; and are accurate record of final quantities measured, to establish normal operating values of the systems.

END OF SECTION 230593