SECTION 230593 - 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 Division 1 Specification Sections, apply to this Section.

B. Division 23 Section "Common Work Results for HVAC"

C. Alternate #6: Refer to Section 012300 – “Alternates”.

1.2 SUMMARY

A. This Section includes testing, adjusting, and balancing (TAB) of mechanical systems.

1.3 SUBMITTALS

A. Use standard forms from AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems." NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems." SMACNA's TABB "HVAC Systems - Testing, Adjusting, and Balancing." TAB firm's forms approved by Architect. TABB "Contractors Certification Manual."

1.4 QUALITY ASSURANCE

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

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

C. TAB Firm Qualifications: Perform all work in accordance with AABC, TABB, or NEBB procedures.

D. TAB Report Forms: Use standard forms from AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems" or NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems".

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

F. Instrumentation Calibration: Calibrate instruments at least every six months or more frequently if required by instrument manufacturer. Keep an updated record of instrument calibration that indicates date of calibration and the name of party performing instrument calibration.

1.5 COORDINATION

A. Coordinate the efforts of factory-authorized service representatives for systems and equipment, HVAC controls installers, and other mechanics to operate HVAC systems and equipment to support and assist TAB activities.

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

C. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

PART 2 - GENERAL

2.1 EXAMINATION AND PREPARATION

A. Prior to commencing testing adjusting and balancing of environmental systems, verify the following HVAC Operational Readiness conditions, if deficiencies are evident, submit Deficiency Report to Architect. Do not begin testing, adjusting, and balancing of environmental system until deficiencies have been remedied.

B. Mechanical contractor shall prepare the systems as required by the Section 230500 Paragraph “Test Adjust and Balance Readiness”.

C. 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.

2.2 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems" NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" SMACNA's TABB "HVAC Systems - Testing, Adjusting, and Balancing" and this Section.

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed. Restore vapor barrier and finish according to insulation Specifications for this Project.

C. Mark equipment and balancing device settings with paint or other suitable, permanent identification material, including damper-control positions, valve position indicators, and

similar controls and devices, to show final settings. Permanently and legibly identify the location points of duct test ports. If the ductwork has exterior insulation, the identification shall be made on the exterior side of the insulation. All penetrations through ductwork and ductwork insulation shall be sealed to prevent air leaks and maintain integrity of vapor barrier.

D. Report on noise problems to the Contractor, A/E, and Owner which are discovered during balancing.

E. Existing Systems T-A-B

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

   a. Existing Air Handler – CFM main duct traverse.

2. Report on the operating condition of the equipment and the results of the measurements taken. Report deficiencies.
3. 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.
4. Perform testing and balancing of existing systems to the extent that existing systems are affected by the renovation work.
5. Compare the indicated airflow of the renovated work to the measured fan airflows and determine the new fan, speed, filter, and coil face velocity.
6. 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.
7. T-A-B procedures for various HVAC systems shall be in accordance with the specification hereinafter.

2.3 TOLERANCES

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

1. Fans: -5% to +10%
2. Supply Air Outlets: 0% to +10%.
3. Exhaust/Return Air Inlets: -10% to 0%
4. Heating-Water Flow Rate: -10% to 0%

2.4 ADDITIONAL TESTS

A. Within 90 days of completing TAB, perform additional testing and balancing to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

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

2.5 FINAL REPORT

A. The TAB activities described shall culminate in a report neatly typed and arranged. Include with the data the date tested, personnel present, and a list of all measurements taken. The intent of the final report is to provide a reference of actual operating conditions for the Owner's operations personnel.

B. Include a list of instruments used for procedures, along with proof of calibration. Include instrument calibration report data: instrument type and make, serial number, application, dates of use, and dates of calibration.

C. Final Report Contents: In addition to certified field report data, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment installers.
5. Other information relative to equipment performance, but do not include Shop Drawings and Product Data.

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

1. Title page.
2. Name and address of TAB firm.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
8. Report date.
9. Signature of TAB firm who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following: Indicated versus final performance, Notable characteristics of systems; Description of system operation sequence if it varies from the Contract Documents.
12. Nomenclature sheets for each item of equipment.
13. Notes to explain why certain final data in the body of reports varies from indicated values.

E. Provide report data for procedures described herein.

PART 3 - TAB PROCEDURES

3.1 PROCEDURES FOR MOTORS – THIS APPLIES TO ALL HVAC SYSTEM MOTORS

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

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

B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass for the controller to prove proper operation. Record observations, including controller manufacturer, model and serial numbers, and nameplate data. Adjust VFDs to skip critical frequencies.

3.2 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

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

1. Quantities of outside, supply, return, and exhaust airflows.
2. Duct, outlet, and inlet sizes.
3. Terminal units.
4. Volume dampers.

B. Test and adjust fan RPM to design requirements. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

C. Test and record motor full load nameplate rating and actual ampere draw.

D. Test and record system static pressures, fan suction, and discharge; static pressure across each component that makes up an air system. Measure static pressures entering and leaving other devices under final balanced conditions.

E. Compare design data with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur.

F. Recommend corrective action to align design and actual conditions. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in all operating modes to determine the maximum required brake horsepower.

G. Adjust all main supply and return air duct to within tolerances of proper design CFM. Make air velocity measurements in ducts by Pitot tube traverse entire cross sectional area of duct in accordance with SMACNA equal area method or Log Linear method. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved. Where sufficient space in sub-main and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone. Re-measure each sub-main and branch duct after all

have been adjusted. Continue to adjust sub-main and branch ducts to indicated airflows within specified tolerances.

H. Test and adjust each diffuser, grille, and register. Reading and tests of diffusers, grilles, and registers shall include design CFM and adjusted CFM.

I. Adjust patterns of adjustable outlets for proper distribution without drafts.

J. Where modulating dampers or economizers are provided, take measurement at full return air, minimum outside air, and100 percent outside air mode of operation.

K. In coordination with the BAS contractor, set adjustments of automatically operated dampers to operate as specified, indicated and/or noted.

L. Adjust outside air automatic and manual dampers for design conditions within specified tolerances.

M. Procedures for Variable-Air-Volume Systems

1. Develop a plan to simulate diversity. When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a maximum set-point airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced airflow terminal units so they are distributed evenly among the branch ducts.
2. After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

    a. Set outside-air dampers at minimum and return- and exhaust-air dampers at a position that simulates full-cooling load.
    b. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
    c. Measure total system airflow. Adjust to within indicated airflow.
    d. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
    e. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow as described for constant-volume air systems. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.
    f. Re-measure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.
    g. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.

h. Record the final fan performance data.

3. Work with the BAS contractor to set up system airflow as indicated in the VAV box schedule – dump box and AHU minimum OA.

N. Air-Handling Unit Test Report: For air-handling units, include the following:

1. Test conditions for fan performance forms including the following:

a. Settings for outside-, return-, and exhaust-air dampers.
b. Conditions of filters.
c. Fan drive settings including settings and percentage of maximum pitch diameter.
d. Settings for supply-air, static-pressure controller.
e. Other system operating conditions that affect performance.

2. Unit Data: Include the following:

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

3. Motor Data: as specified hereinbefore.
4. Test Data (Indicated and Actual Values):

a. Total airflow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Filter static-pressure differential in inches wg.
f. Coil static-pressure differential for each coil in inches wg.
g. Outside airflow in cfm.
h. Return airflow in cfm.
i. Outside-air damper position.
j. Return-air damper position.
k. Supply and Return Fan VFD Hz.

O. Fan Test Reports:

1. Fan Data:

a. System identification.
b. Location.
c. Make and type.

d. Model number and size.
e. Manufacturer's serial number.
f. Arrangement and class.
g. Sheave make, size in inches, and bore.
h. Sheave dimensions, center-to-center, and amount of adjustments in inches.
i. Number of belts, make, and size.

2. Motor Data: as specified hereinbefore.
3. Test Data (Indicated and Actual Values):

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

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

1. Report Data:

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

Q. Air-Terminal-Device Reports, VAV

1. Unit Data:

a. Manufacturer, type size, and fittings.
b. System and air-handling unit identification.
c. Location and zone.
d. Test apparatus used.
e. Area served.
f. Air-terminal-device manufacturer and model.
g. Air-terminal-device number from system diagram.
h. Air-terminal-device type and model number.
i. Air-terminal-device size.

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.
b. Air velocity in fpm.
c. Preliminary airflow rate as needed in cfm.

d. Preliminary velocity as needed in fpm.
e. Final airflow rate in cfm.
f. Final velocity in fpm.

R. Air-to-Air Energy-Recovery Unit Reports

1. Unit Data:

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

2. Motor Data: as specified herein before.
3. Test Data (Indicated and Actual Values):

a. Total exhaust airflow rate in cfm.
b. Outside airflow rate in cfm.
c. Total exhaust fan static pressure in inches wg.
d. Total outside-air fan static pressure in inches wg.
e. Pressure drop on each side of recovery wheel in inches wg.
f. Exhaust air temperature entering in deg F.
g. Exhaust air temperature leaving in deg F.
h. Outside-air temperature entering in deg F.
i. Outside-air temperature leaving in deg F.

S. Procedures for Heat-Transfer Coils

1. Coil Test Reports:

a. System identification.
b. Location.
c. Make and model number.
d. Face area in sq. ft.

2. Test Data (Indicated and Actual Values):

a. Airflow rate in cfm.
b. Face area in sq. ft.
c. Average face velocity in fpm.
d. Air pressure drop in inches wg.
e. Water flow rate in gpm.
f. Water pressure differential in feet of head.

3.3 PROCEDURES FOR HYDRONIC SYSTEMS

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

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

1. Water flow rates.
2. Pipe and valve sizes and locations.
3. Terminal units.

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

1. Open all manual valves for maximum flow.
2. Check expansion tank liquid level.
3. Check makeup-water-station pressure gage for adequate pressure for highest vent.
4. Check flow-control valves for specified sequence of operation and set at indicated flow.
5. Set system controls so automatic valves are wide open.
6. Check air vents for a forceful liquid flow exiting from vents when manually operated.

D. Hydronic balancing shall include the following minimum data:

1. Prepare itemized equipment schedules, listing all hydronic elements and equipment in the systems to be balanced. List in order on equipment schedules, by pump or zone according to the design, all hydronic elements, all zone balancing valves, and circuit pumps, ending with the last items of equipment or transfer element in the respective zone or circuit. Include on schedule sheet column titles listing the location, type of element or apparatus, design conditions, and measured conditions. Prepare individual pump report sheets for each zone or circuit.
2. Adjust systems to provide specified pressure drops and flows through heat transfer elements prior to thermal testing. Perform balancing by measurement of temperature differential in conjunction with air balancing.
3. Effect system balance with automatic control valves fully open to heat or cooling transfer elements.
4. Adjust balancing valves at each coil and balancing valve for design flow. Adjust hydronic distribution systems by means of balancing valve; do not use service or shut-off valves for balancing unless indexed for balance point.
5. Water pressure shall be recorded at all gauge connections

E. For coils equipped with three-way valves, the rated pressure drop shall first be adjusted through the coils. The bypass valve shall then be adjusted on each coil until an equal pressure drop between supply and return connections is the same as with the flow through the coil.

F. Pumps:

1. Adjust balancing valves or VFD at pumps to obtain design water flow. Record pressure rise across pumps and GPM flow from pump curve. Permanently mark the balanced position for each valve. (Note: If discharge valves on the pumps are used for balancing, record the head being restricted by the valves).
2. Where available pump capacity is less than total flow requirements or individual system parts, proportional balancing must be performed.
3. Do not deadhead the pumps. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded. Running amps and brake horsepower of pump motor under full flow and no flow conditions.

4. Calculate impeller size by plotting the shutoff head on pump curves and include the following pump test report data:
5. Unit Data:

    a. Unit identification.
    b. Location.
    c. Service.
    d. Make and size.
    e. Model and serial numbers.
    f. Water flow rate in gpm.
    g. Water pressure differential in feet of head or psig.
    h. Pump rpm.
    i. Impeller diameter in inches.
    j. Motor Data: as specified herein before.

6. Test Data (Indicated and Actual Values):

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

G. Procedures for Heat Exchangers

1. Measure water flow through all circuits. Adjust water flow to within specified tolerances. Measure inlet and outlet water temperatures. Check the setting and operation of safety and relief valves. Record settings.
2. Heat-Exchanger/Converter Test Reports: Include the following:

    a. Unit Data:

        1) Unit identification.
        2) Location.
        3) Service.
        4) Make and type.
        5) Model and serial numbers.

    b. Steam Test Data (Indicated and Actual Values): Inlet pressure in psig.
    c. Secondary Water Test Data (Indicated and Actual Values):

        1) Entering-water temperature in deg F.
        2) Leaving-water temperature in deg F.
        3) Entering-water pressure in feet of head.
        4) Water pressure differential in feet of head.

5) Water flow rate in gpm.

3.4 PROCEDURES FOR EXHAUST HOODS

A. Kitchen Hoods

1. Measure, adjust, and record the airflow of each kitchen hood.

3.5 TESTING OF BUILDING AUTOMATION SYSTEMS

A. Assist the BAS Contractor as follows:

1. Work with the Temperature Control Contractor to ensure the most effective total system operation is within the design limitations, and to obtain mutual understanding of intended control performance.
2. Verify that all control devices are properly connected and operated by the intended controller.
3. Observe that all valves are properly installed in the piping system in relation to direction of flow and location.
4. Observe the calibration of all controllers.
5. Verify the proper application of all normally opened and normally closed valves.
6. Observe the locations of all sensors to determine whether their position will allow them to sense only the intended temperatures or pressures of the media. The Control Contractor shall relocate as deemed necessary by the TAB Agency.
7. Verify that the sequence of operation for any control mode is in accordance with approved shop drawings and specifications.
8. Verify the operation of all interlock systems.
9. Perform variable volume system verification to assure the system and its components track with changes from full flow to minimum flow.

END OF SECTION 230593