SECTION 23 05 93
TESTING, ADJUSTING AND BALANCING FOR HVAC

PART 1 – GENERAL

1.01 WORK INCLUDED

A. The work of this Section shall include, but is not limited to, the following:

1. Adjust and balance hydronic systems.
2. Adjust and balance air systems.
3. Perform acoustic measurements to systems.
4. Perform airflow measurements for smoke control system zones and stair and vestibule pressurization tests.

1.02 RELATED DOCUMENTS

A. Section 22 11 00 – Domestic Water Systems

B. Section 23 05 01 – HVAC General Provisions

C. Section 23 05 14 – Variable Frequency Drives for HVAC

D. Section 23 05 23 – General-Duty Valves for HVAC Piping

E. Section 23 09 93 – Sequence of Operations for HVAC Controls

F. Section 23 21 23 – Hydronic Pumps

G. Section 23 33 13 – Dampers

H. Section 23 34 00 – HVAC Fans

I. Section 23 36 00 – Air Terminal Units

J. Section 23 37 00 – Air Outlets and Inlets

1.03 REFERENCE STANDARDS

A. All work shall be in accordance with the Associated Air Balance Council (AABC) Standards.

1.04 QUALITY ASSURANCE

A. Each Testing, Adjusting, and Balancing (TAB) contractor providing a bid for this work shall submit the following information with the bid, or the bid shall not be accepted by the Owner:

1. List previous projects of similar scope with dates that projects were executed.
2. Outline organization of the TAB contractor, including names of principals, years of operation, address, and phone number.
3. List instruments owned by the TAB contractor and procedures that will be used on this project.
4. List name of job site supervisor that will execute this work and a résumé of individual’s specific work experience.

5. Provide a sample of a balance report on a project of similar scope.

B. The final testing, adjusting, and balancing of the complete mechanical systems shall be the direct responsibility of the TAB contractor, including all costs for doing this work and provision of the personnel, materials, tools, and instrumentation to accomplish this work. Meet standards contained in the AABC National Standard Chapter 17 through 26 and other criteria as set forth in these specifications.

C. The TAB contractor shall be independent, and certified by the AABC for testing, adjusting, and balancing of plumbing and heating, ventilating and air conditioning systems. The TAB contractor shall be AABC certified.

D. Provide an AABC national performance guaranty document for the specific project.

1.05 SUBMITTALS

A. Three months prior to the start of the TAB field activities, submit certification of most recent calibration of all instruments to be used on this project.

B. Submit project-specific agenda (outline) as described in Paragraph 1.06B.

C. Submit sample forms as described in Paragraph 1.06E.

D. Submit testing, adjusting, and balancing report as described in Paragraph 3.04.

1.06 PROCEDURES

A. General: prior to commencement of balancing, review proposed schedule, methods and instruments to be used in balancing with the Architect. Include descriptive data, procedure data and sample forms.

B. Descriptive data: review contract documents, shop drawings released for construction, design concepts and general function of each system including associated equipment and operation cycles. Confirm listing of flow and terminal measurements to be performed. Confirm selection points for proposed sound measurements if applicable.

C. Procedure data: outline procedures for taking test measurements to establish compliance with requirements. Specify type of instruments to be used, method of instrument application (by sketch) and correction factors. Verify access to valves, dampers and equipment for test and balancing.

D. Sample forms: submit forms showing application of procedures to typical systems. Forms shall be of AABC format.

E. AABC test sheets required are as follows:

1. Air moving equipment test sheet
2. Exhaust fan test sheet (supply, return, relief fans)
3. Air inlet and outlet test sheet
4. Water balance element test sheet
5. Circulating water pump data sheet
6. Duct traverse zone totals sheet
7. Duct traverse readings sheet

1.07 INSTALLING CONTRACTOR COOPERATION

A. The TAB contractor shall check and report defects or deficiencies that may affect balancing.

1. Division 23 (mechanical) contractor shall cooperate with the TAB contractor to:

a. Provide sufficient time before final completion date and individual equipment manufacturer's start-up so that testing, adjusting, and balancing can be accomplished.
b. Provide immediate materials, labor and tools to make corrections without delay.
c. Place heating, ventilating and air-conditioning systems and equipment into full operation and continue the operation for each working day of testing and balancing.
d. Advise TAB contractor of changes made to the system during construction.
e. Install required test holes or wells complete with removable and replaceable plugs or caps.
f. Make necessary revisions to controls, valves, dampers, fan drives, and pump drives, and consult with equipment manufacturers as required to achieve the specified system's performance.
g. Supply and install dampers as specified and shown on the Drawings, where required, and where directed by the TAB contractor to obtain efficient and effective system balance.
h. Provide lifts, ladders, scaffolds, tools and labor to assist the work of the TAB contractor, including removing ceiling tiles, guards, adjusting pulleys, belts; replace when finished.
i. Building Management System (BMS) contractor shall cooperate with and work with the TAB contractor when setting damper linkages, minimum outside air dampers, and other air volume devices, and shall be available for readjusting of dampers, devices or controls that are not calibrated. The BMS contractor shall also provide all software, cabling, and other devices necessary to perform the testing, adjusting, and balancing.
j. Set pressure-regulating and pressure-reducing valves to operating and code conditions.
k. Check and set relief valves and safety valves to code requirements.
l. Clean strainers. Check air filters immediately prior to air balancing.
m. Open fire dampers. Provide certification of damper operation as required by Section 23 33 13 – Dampers.
n. Verify return air openings have been provided in full height walls as specified, shown on the Drawings or as required for balancing and system operation.
o. Variable pitch sheaves supplied on 20-horsepower motors and larger shall be changed to fixed sheaves after the air balance is completed. Provide such sheaves.

PART 2 – PRODUCTS

2.01 INSTRUMENTS

A. Instruments for testing, adjusting, and balancing of air and hydronic systems shall have been calibrated within a period of 6 months and verified for accuracy prior to start of work.

B. Submit a list of equipment, which will be used for the testing, adjusting, and balancing of systems.

C. Submit test and calibration certifications by an independent instrument calibration laboratory indicating date of test, and test results showing accuracy and repeatability are within limitations acceptable under AABC standards.

PART 3 – EXECUTION

3.01 GENERAL PROCEDURE

A. Balance to maximum measured flow deviation from specified values of 10 percent at terminal device and 5 percent at equipment or mean sound-level deviation of 15 decibels.

B. Permanently mark settings on valves, splitters, dampers and other adjustment devices.

C. Take measurements to verify balance has not been disrupted or that such disruption has been rectified.

D. At final inspection, re-check random selections of data recorded in report. Recheck points or areas as selected and witnessed by the Architect.

E. At the completion of testing, adjusting, and balancing procedures, allow for a minimum of 2 days for the Architect to witness test procedures and conduct operational tests.

3.02 SITE VISITS

A. A review of the installation shall be made prior to commencing testing, adjusting, and balancing work, and any additional dampers or valves required for balance shall be reviewed with the Architect and the Contractor.

B. The TAB contractor shall review the field installation progress a minimum of 3 times during the plumbing, ductwork, equipment and piping installations at approximately 50, 75, and 90 percent installation completion, or other milestones. The last job site review shall be prior to ceiling closure. Site visit reports shall be submitted to the Architect listing any deficiencies found. Identify in the Report any additional balancing valves or dampers required.

3.03 ACCEPTANCE

A. Mechanical systems shall not be considered ready for final inspection until testing, adjusting, and balancing results acceptable to the Architect are obtained.

B. If it is found that the specified airflows cannot be achieved on portions of the system, the actual conditions shall be reported to the Architect for consideration of corrective action before continuing the testing, adjusting, and balancing procedure.

C. If measured flow at final inspection shows deviation of 10 percent or more or mean sound-level deviation of 10 decibels or more from the certified report listings for more than 10 percent of selected areas, the TAB report shall be rejected.

D. If report is rejected, systems shall be re-tested, adjusted, and balanced, and a new certified report submitted.

3.04 BALANCING REPORT

A. Submit a draft copy of TAB reports prior to final acceptance of project. Provide copies of final report for inclusion in Operating and Maintenance Manuals.

B. Provide TAB reports in durable soft cover, 3-ring binder manuals, complete with table of contents, indexing tabs and cover identification at front and side.

C. Include types, serial number and dates of calibration of instruments.

D. Record test data on the latest available revised set of mechanical shop drawings and submit copies upon completion of the tab contract.

E. Install at each piece of mechanical equipment a Data Register showing significant operating temperatures, pressures, amperes, voltage, and brake horsepower. Data Register shall be enclosed in a hard, clear plastic holder securely attached to the equipment or to a wall in the adjacent area.

F. Submit with TAB report, fan and pump curves with operating conditions plotted.

G. TAB report shall be indexed as follows:

1. Air

a. Summary
b. Procedure
c. Instrumentation
d. Drawings
e. Equipment summary
f. Fan sheets
g. Fan curves
h. Fan profile data
i. Static data
j. Air monitoring station data
k. Traverse data and schedule
l. Terminal unit summary
m. Outlet data summary and schematics (per system)
n. Building pressurization data

o. Smoke exhaust mode data
p. Stairway and stair vestibule pressurization data
q. Smoke control system testing (smoke control zone supply, relief and exhaust capacities)

2. Water

a. Summary
b. Procedure
c. Instrumentation
d. Pump data
e. Pump curves
f. Flow stations
g. Coils

h. Equipment data
i. Element data summary and schematics (per system)

3. Sound

a. Summary
b. Procedure
c. Instrumentation
d. Drawings
e. Profile
f. Scale readings

4. Copy of TAB contractor's AABC certification and quality assurance guarantee.

3.05 AIR SYSTEM PROCEDURE

A. Execute air systems testing, adjusting, and balancing for each air system in accordance with AABC specifications and as described herein. Prior to initiating this work, verify that air system has been cleaned, and that a dust free environment exists to minimize internal duct contamination. Use temporary air filter media covering all return and exhaust registers to protect ductwork.

B. Make tests with supply, return and exhaust systems operating and doors, windows, closed or in their normal operation condition.

C. Test, adjust, and balance fan or blower speed to design requirements.

D. Test and record motor full load amps. Record each installed motor manufacturer and motor efficiency.

E. Traverse main supply air ducts, using a pitot tube and manometer. Calibrate the manometer to read two significant figures in velocity and pressure ranges. Obtain a minimum of 16 readings per traverse. The intent is to measure by traverse the total air quantity supplied by the fan and to verify the distribution of air to zones. A main duct is defined as any of the following:

1. A duct serving 5 or more outlets.
2. A duct serving 3 or more branch ducts.
3. A duct serving a hydronic coil.
4. A zone duct from a fan-powered VAV terminal unit.
5. A duct emanating from a fan discharge or plenum and terminating at one or more outlets.

F. Submit data in support of supply fans deliveries by the following four methods. For return, relief and exhaust fans, methods 1 and 4 are sufficient:

1. By summation of the air quantity readings at inlets or outlets.
2. By duct traverses of main supply ducts.
3. By traverse across the filter bank or coil bank.
4. By plotting revolutions per minute and static pressure readings on the fan curve. Air density corrections shall be indicated.

G. Test, adjust, and record required and measured system static pressures; filter differential

pressure, coil differential pressure, damper differential pressure and fan total static pressure.

H. Test, adjust, and balance systems for design recirculated airflow rates.

I. Test, adjust, and balance system for design minimum, and economizer outside airflow rates.

J. Test, adjust, balance and record entering and leaving air temperatures for heating and cooling.

K. Install disposable media filters upstream of air filters to temporarily impose 90 percent of the manufacturer's recommended final filter air pressure drop. Measure and record fan performance data to ensure the fan capacity maintains design conditions with filters loaded.

L. Test, adjust, and balance main supply and return ducts to design flow rates. One direct path from a fan to a terminal outlet device shall include a fully open balancing damper. Document all paths that have open volume dampers on final balance report to verify that over balancing has not occurred. The intent is to test, adjust, and balance a VAV terminal unit being 90 to 95 percent open.

M. Prior to the start of testing, adjusting, and balancing, the installing contractor shall inspect and confirm fire dampers are open, smoke dampers and fire/smoke dampers are in their correct position, duct access doors are closed and fire damper fusible links are accessible.

N. Test, adjust, and balance zones to design, supply and return flow rates.

O. Test, adjust, and balance each air inlet and air outlet and transfer duct to within 10 percent of design requirements.

P. Identify each air inlet, air outlet, transfer duct and transfer wall opening as to location and area.

Q. Identify and list size, type and manufacturer of diffusers, grilles, registers and testing equipment. Use manufacturer's rating on equipment to make required calculations.

R. In readings and tests of diffusers, grilles and registers, report the required face and neck velocity, test face and neck velocity, and required air pressure drop and flow rate. Test after adjustments.

S. BMS contractor shall set adjustments of VFDs and automatic dampers to operate as indicated, in cooperation with TAB contractor.

T. Test, adjust, and balance diffusers, grilles and registers to minimize drafts, dumping, and to prevent short circuiting between supply and return outlets.

U. Use volume control devices to regulate air quantities only to extent that adjustments do not create objectionable air motion or sound levels. Effect volume control by duct internal devices such as dampers and splitters. Remove air slots on return air troffers to achieve room pressure relief and minimize pressure drop into the ceiling plenum.

V. Vary total system airflow rates by adjustment of fan speeds or fan volume-varying devices. Vary branch air quantities by damper regulation.

W. Record installed fan drive assemblies; fan sheaves, motor sheaves, belts and motors.

X. For fans with two-speed motors, execute the entire air systems procedure at both speeds. This also applies to fans with variable frequency drives when used in normal mode and multiple smoke control modes.

Y. The final balanced condition of each area shall include testing, adjusting, and balancing of pressure conditions. Test and record building pressurization levels in variable volume systems throughout the full range of fan delivery rates, under both heating and cooling conditions. For multi-story buildings, test pressure conditions at ground, intermediate and upper levels. Front doors, stair and vestibule doors, exits, elevator machine rooms, relief dampers, and elevator hoistways shall be checked for airflow so that leakage does not cause excessive or abnormal pressure conditions. Document abnormal building leakage conditions noted.

Z. Complete balancing to achieve positive building pressure unless otherwise instructed. A positive pressure relative to outside between 0.05-inch water gauge minimum and 0.10-inch water gauge maximum shall be achieved, measure with negligible, outside wind velocity.

AA. Complete balancing of the refrigeration machinery room intake and exhaust air systems to maintain a negative pressure of 0.05-inch water gauge minimum relative to adjacent spaces.

BB. Test, adjust, and balance stair and stair vestibule pressurization fans. Measure air quantity delivered by fan and inlet points. Measure airflow rate through relief openings in stair. Measure pressure differential between normally occupies adjacent areas, stair vestibule and stair in three locations per stair (2nd floor, mid-height, top floor). These systems shall be tested, adjusted, and balanced as required by the smoke control report. Refer to the smoke control report for various modes and conditions required for acceptance by the Authorities Having Jurisdiction.

3.06 FIRE AND LIFE SAFETY VENTILATION SYSTEMS PROCEDURE

A. All testing, adjusting, and balancing is required for equipment, systems and terminal devices during normal operation and fire alarm and life safety operation.

B. The life safety and smoke control and ventilation systems shall be performance tested by demonstration of the sequences of the fire and life safety ventilation system, automatic damper operation, stair and vestibule door opening and closing forces and other functions involved. Tests shall demonstrate the activation of the smoke detection system and smoke control system, in accordance with the procedures and test criteria established by the local Authorities Having Jurisdiction. The mechanical, fire protection, fire alarm, electrical, and Building Management System contractor and the General contractor shall be present and shall participate during the entire testing procedures. The mechanical contractor shall furnish the smoke generators, ladders, tools, etc.

C. The TAB contractor shall verify and record that the required pressure differences, the quantity of air required, specified or indicated on the Drawings is supplied, relieved or exhausted. Tests shall demonstrate the sequences of the life safety ventilation systems, the activation of the smoke detection system, the activation of the smoke control system, and the make-up air systems. The smoke control systems installed in this Project shall be performance tested and demonstrated in accordance with the requirements of the

Authorities Having Jurisdiction and the Fire Department. The demonstration tests shall be conducted and repeated until they are accepted and approved by the Authorities Having Jurisdiction. The mechanical contractor shall include all costs associated with the required demonstration tests, including smoke generators, instrumentation, etc. Perform a minimum of one successful test of each sequence witnessed by the Architect prior to any demonstration test for Authorities Having Jurisdiction.

3.07 HYDRONIC SYSTEMS PROCEDURE

A. Preparation of System – Phase I: The hydronic system shall be prepared for testing, adjusting, and balancing as followings:

1. Open valves to full position including coil stop valves; close bypass valves; and return line balance valves.
2. Examine water in each system to determine if it has been chemically treated, and is clean.
3. Check pump rotation.
4. Check expansion tanks to ensure that they are not air bound and that the system is full of water.
5. Check air separators and air vents at hydronic coils and high points of water systems to ensure that they are installed and operating freely. Verify all air is removed from circulating system.
6. Set temperature controls to close automatic bypass valves and provide full flow through hydronic coils or heat exchangers.
7. Check operation of automatic bypass valves.
8. Check and set operating temperature of heat exchangers, cooling towers, boilers and chillers at design requirements.
9. Execute air balance before water balance is initiated.

B. Test and Balance Procedure – Phase II:

1. Check operation of variable speed pumps and record pump data at varying percentages of full flow.
2. Set pumps to deliver approximately 10 percent excess flow volume if possible. Do not overload motors.

3. Adjust flow through chillers, heat exchangers, cooling towers and boilers.
4. Check and record entering and leaving water temperatures and pressure drop through chillers, boilers, cooling towers and heat exchangers. Reset to design temperatures.
5. Check and record water temperature at inlet side of coils. Note rise or drop of temperatures from source.
6. Where automatic flow control valves are installed, verify that the operating pressure differential across the valves are within the range indicated on the submittal data sheet.
7. Position and mark/lock manual calibrated balance valves for design flow through coils, AC units, heat pumps, convectors and all other items in system requiring circulation of glycol, chilled water, hot water or condenser water.
8. For venturi type, pitot tube, or other flow measuring devices, record the pipe size, manufacturer and size of device, and the direct reading of the differential pressure, and calculated final flow.
9. Upon completion of flow readings and coil adjustments, mark settings and record data.

10. Ensure bypass valves are fully closed.

C. Test and Balance Procedure – Phase III:

1. After testing, adjusting, and balancing coils, recheck settings at pumps. Re-test and re-adjust if required.
2. Install pressure gauges on each coil to indicate pressure drop through coil, and set flow rate on a demand for full flow through the coils. Set pressure drop across bypass valves to match coil full flow pressure drop.
3. Balance flow through equipment and coils by means of pressure drop. Obtain performance curves from the manufacturers indicating the relationship between flow and pressure drop through the coils and equipment. Record readings on calibrated test gauges.
4. Upon completion of the water balance, reconcile the total heat transfer through coils by recording the entering and leaving water temperatures and the entering and leaving air dry bulb and wet bulb temperatures.
5. Upon completion of testing, adjusting, and balancing, adjust differential bypasses for the same pressure drop on full bypass as on full flow.

3.08 BALANCING DATA

A. Air handling equipment installation data:

1. Manufacturer, model and size.
2. Arrangement, discharge and class.
3. Motor type, horsepower, speed, efficiency, voltage, phase, cycles and full load amperes.
4. VFD manufacturer, model and documentation of final parameter settings.
5. Location and final identification.

B. Air handling equipment design data:

1. Total airflow rate.
2. Static pressure across coil, filter, dampers, mixing box sections and total.
3. Motor horsepower, speed, efficiency, voltage and amperes.
4. Fan speed and brake horsepower.
5. Hydronic coil inlet and outlet, dry bulb temperatures.
6. Initial filter air pressure drop.

C. Air handling equipment recorded data:

1. Total airflow rate
2. Static pressure across coil, filter, damper, mixing box sections and total
3. Fan speed and brake horsepower
4. Motor operating amperes
5. VFD final operating speed (hertz) at design flow
6. Inlet and outlet, dry bulb temperatures
7. Filter air pressure drop
8. Manufacturer’s fan curves with field measured operating points identified
9. Outside air quantity measurement

D. Duct air quantities: mains, branches, outside air and exhausts (maximum and minimum):

1. Duct sizes
2. Number of pressure readings
3. Sum of velocity measurements
4. Average velocity
5. Duct recorded airflow rate
6. Duct design airflow rates

E. Air inlets and outlets:

1. Inlet/outlet identification location and designation
2. Manufacturer's catalogue identification and type
3. Application factors
4. Design and recorded velocities
5. Design and recorded airflow rates
6. Deflector vane or diffuser cone settings
7. Identify duct sections with volume dampers fully opened. Include BMS graphics screen captures to document that optimized balance has been achieved with applicable setpoints and control parameters identified for these duct sections.

F. Building pressurization data:

1. Outside air temperature and humidity
2. Outside wind velocity
3. Building pressures plotted with respect to systems
4. Supply air, return air and exhaust airflow rates for varying damper positions
5. Locations of pressure measuring points, inside and outside building

G. Stair and stair vestibule pressurization data:

1. Stair Supply airflow rates
2. Exhaust or relief opening flow rates
3. Vestibule to floor pressure differential each floor
4. Stair to vestibule pressure differential each floor

H. Smoke exhaust data: supply and exhaust flow rate

I. Pump installation data:

1. Manufacturer, model and size
2. Impeller diameter
3. Drive type
4. Motor type, horsepower, efficiency, speed, voltage, phase, cycles and full load motor amperes

J. Pump design data:

1. Flow rate and head pressure
2. Pump speed and horsepower
3. Pump efficiency

K. Pump recorded data:

1. Discharge and suction pressures (full flow and no flow)

2. Operating pressure and total dynamic head
3. Operating rate (from pump curves if metering not provided or from variable speed controller). Identify operating range on pump curves.
4. Motor operating amperes
5. Balancing valve setting (full open, 60-percent open etc.)
6. Identify piping sections with adjustable balancing valves fully opened. Include BMS graphics screen captures to document that optimized balance has been achieved with applicable setpoints and control parameters identified for these piping sections.

L. Expansion tank installation data:

1. Manufacturer, size, capacity
2. Pressure reducing valve setting
3. Pressure relief valve setting

M. Heating equipment design data:

1. Heat transfer rate
2. Flow rates and pressure drops
3. Entering and leaving water temperature

N. Heating equipment recorded data:

1. Element type and identification (location and designation)
2. Entering and leaving temperatures
3. Flow rates and pressure drops

O. Air heating and cooling equipment design data:

1. Heat transfer rate
2. Water pressure drop across coil
3. Air static pressure drop
4. Entering and leaving water temperatures
5. Entering and leaving air dry and wet bulb temperatures

P. Air heating and cooling equipment recorded data:

1. Element type and identification
2. Entering and leaving air dry and wet bulb temperatures
3. Entering and leaving water temperatures
4. Water pressure drop across coil
5. Water pressure drop across bypass valve
6. Air static pressure drop
7. Air and water flow rates
8. Adjusted temperature rise or drop

Q. Water chiller installation data:

1. Manufacturer and model
2. Motor type, kilowatts, speed, voltage, cycles, phase and full load amperes
3. Water flow rates
4. Water pressure drops

5. Entering and leaving water temperatures

R. Water chiller recorded data:

1. Water flow rates
2. Water pressure drops
3. Entering and leaving water temperatures
4. Running load kilowatts

S. Sound level data:

1. Diagram or description of relationship of sound source to measuring instrument
2. Overall decibels (A) level
3. Reading at each octave band frequency from 31.5 Hz to 16 kilohertz
4. Noise criteria (NC) curves plotted and compared to those recommended by ASHRAE or AABC publications

T. Sound level recorded data:

1. Air inlets and outlets
2. VAV terminal units
3. Air handling units
4. Chillers
5. Cooling towers
6. Boilers
7. Variable frequency drives
8. Fans
9. Air conditioning units and heat pumps

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