

## SECTION 23 05 93

### TESTING, ADJUSTING, AND BALANCING FOR HVAC

#### PART 1 - GENERAL

##### 1.01 SECTION INCLUDES

- A. Testing and balancing of air handling system.
- B. Testing of air conditioning units.
- C. Testing of heating pumps.
- D. Testing of electric duct or unit heating coil.
- E. Sound tests.
- F. Documentation.

##### 1.02 RELATED SECTIONS

- A. Section 01 33 00 – Submittal Procedures
- B. Section 01 33 23 - Shop Drawings, Product Data, and Samples
- C. Section 01 45 00 – Quality Control
- D. Section 23 09 00 – Instrumentation and Control for HVAC
- E. Section 23 31 00 - HVAC Ducts and Casings

##### 1.03 MEASUREMENT AND PAYMENT

- A. General: Separate measurement of payment will not be made for the work required under this Section. All costs in connection with the Work specified herein will be considered to be included or incidental to the Work of this Contract.

##### 1.04 REFERENCES

- A. Associated Air Balance Council (AABC):
  - 1. AABC MN-1 National Standards for Total System Balance
- B. American National Standards Institute (ANSI):
  - 1. ANSI S1.4 Specification for Sound Level Meters
  - 2. ANSI S1.11 Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters
  - 3. ANSI S1.13 Methods for the Measurement of Sound Pressure Levels

- C. American Society of Heating, Refrigerating, and Air Conditioning Engineers Inc. (ASHRAE):
  - 1. ASHRAE Handbook, HVAC Applications
  - 2. ASHRAE Handbook, HVAC Systems and Equipment
- D. National Environmental Balancing Bureau (NEBB):
  - 1. NEBB Procedural Standards for Testing, Adjusting, Balancing of Environmental Systems
- E. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA):
  - 1. SMACNA HVAC Systems Testing, Adjusting and Balancing
- F. ADC Test Code for Grilles, Registers and Diffusers.

## **1.05 SUBMITTALS**

- A. General: Refer to Section 01 33 00 - Submittal Procedures, and Section 01 33 23 - Shop Drawings, Product Data, and Samples, for submittal requirements and procedures.
- B. Warranty: Submit AABC National Warranty Certificate for the completed installation.
- C. Preliminary Report: Examine the installed systems and submit a written preliminary report to Engineer indicating any deficiencies in the systems that could preclude the proper adjusting, balancing, and testing of the systems. Resolve deficiencies as required.
- D. Agenda: The Contractor shall submit an agenda for approval by the Engineer prior to start of testing and balancing work. The agenda shall include the following information:
  - 1. General description of each HVAC system with its associated equipment and operation cycles for heating, intermediate, and cooling. Where different cycles are used for day and night, they shall be described separately.
  - 2. A complete listing of all airflow and air terminal measurements to be performed.
  - 3. Proposed selection points for sound measurements.
  - 4. Specific test procedures and parameters for determining specified quantities (e.g., flow, drafts, sound levels) from the actual field measurements to establish compliance with contract requirements.
  - 5. Samples of report forms with blank spaces for all data specified herein. These forms shall demonstrate applications of procedures and calculations to typical systems.
- E. Test Procedures: Specific test procedures for measuring air quantities at terminals shall be submitted to specify type of instrument to be used, method of instrument application (by sketch), and factors for the following conditions:
  - 1. Air terminal configuration;

2. Flow direction, supply or exhaust;
  3. Velocity corrections;
  4. Effective area applicable to each size and type of air terminal; and
  5. Density corrections unless applicable data are covered elsewhere.
- F. Sample Forms: Submit sample forms, if forms other than those prepared by the AABC or NEBB are proposed.
- G. Instrument Calibration: Submit certified documentation showing test instrument calibration data and date.
- H. Test Reports: Submit certified test reports for each system, including information as specified.
- I. Calibration Reports: Submit proof that all required instrumentation has been calibrated to tolerances specified in the referenced standards, within a period of six months prior to starting the project.

#### **1.06 QUALITY ASSURANCE**

- A. Perform testing, adjusting, and balancing, using the services of an independent testing and balancing agency regularly engaged in the testing and balancing of air and water systems and associated equipment and piping systems. The agency selected shall be a certified member of the Associated Air Balance Council (AABC). The agency shall be independent of the installing personnel or equipment supplier for this project.
- B. Work shall be performed in accordance with the agenda specified herein. Procedures and methods specified herein shall be followed and, if not specifically specified herein, shall be performed in accordance with the AABC MN-1; NEBB Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems; SMACNA HVAC Systems Testing, Adjusting and Balancing; ASHRAE Handbook, HVAC Applications; and ASHRAE Handbook, HVAC Systems and Equipment.
- C. Provide test results and final reports certified and signed by a professional mechanical engineer currently registered in the State of California.
- D. Prior to beginning of the testing, adjusting, and balancing procedures, schedule and conduct a pre-balancing conference with the Engineer, and representatives of installers of the mechanical systems. The objective of the conference is final coordination and verification of system operation and readiness for testing, adjusting, and balancing.
- E. Test, adjust, and balance the air systems before testing, adjusting, and balancing of the hydronic, steam, and refrigerant systems, as applicable.

#### **1.07 PROJECT CONDITIONS**

- A. Pre-Balancing Requirements:

1. Prior to testing or starting, clean inside of each piece of equipment and provide clean filters.
  2. Prior to any startup, obtain Engineer's approval of test procedures for airflow testing, adjusting, and balancing.
- B. System Operation:
1. Testing and balancing shall not begin until each system has been completed and is in full working order. Put all heating, ventilating, and air-conditioning systems and equipment, including controls, into full operation and continue the operation of the systems during each working day of testing and balancing.
  2. Tests shall be performed and adjustments made as necessary to accomplish the design objectives.
  3. In systems with two or more operating modes, the system operation in the primary mode shall be tested, balanced, and adjusted. After final adjustment in the primary mode, the secondary modes shall be tested, and the system data recorded. The Engineer will determine whether additional balancing and adjusting are necessary to meet the requirements.
  4. In systems with redundant equipment, each piece of equipment shall be tested and adjusted independently to operate within the design criteria.
- C. Readjustments: Should corrective measures caused by faulty installation require retesting, adjusting, and balancing, such work shall be performed at no additional cost to the District.

## **PART 2 - PRODUCTS**

### **2.01 INSTRUMENTATION**

- A. All systems and related components shall be adjusted to perform as required by the Contract Drawings and Specifications.
- B. Operating tests of heating and cooling coils, fans, and other equipment shall be of not less than four hours duration after stabilized operating conditions have been established. Capacities shall be based on temperature and airflow quantities measured during such tests.
- C. Method of application of instrumentation shall be in accordance with the approved agenda.
  1. All instruments used for measurements shall be accurate, and calibration histories for each instrument shall be available for examination. Each test instrument shall be calibrated by an approved laboratory or by the manufacturer. The Engineer has the right to request instrument recalibration, or the use of other instruments and test methodology, where accuracy of readings is questionable. Refer also to Section 01 45 00 - Quality Control, for requirements.
  2. All instruments shall be applied in accordance with manufacturer's certified instructions.

3. Furnish all labor, instruments, and appliances required to perform the specified instrumentation. Permanently installed instruments used for the tests, such as gages and thermometers, shall not be installed until just prior to the tests to avoid damage and changes in calibration.
4. Accuracy of all thermometers shall be plus or minus 1 graduation at the temperatures to be measured. Graduations shall conform to the following schedule:

<u>Design Temperature Differential Degrees F</u>	<u>Maximum Graduation Degrees F</u>
10 or less	0.5
over 10	1

- D. Instruments that require calibration shall have unexpired calibration dates. Instruments shall be calibrated against certified equipment having a known valid relationship to nationally recognized standards. If no national standard exists, the basis for calibration shall be documented and submitted in the final report.
- E. Certified documentation of all instrument calibrations shall be submitted in the final report.

**PART 3 - EXECUTION**

**3.01 APPLICABLE STANDARDS**

- A. Perform testing and balancing in accordance with AABC MN-1 and the hereinbefore-referenced NEBB, ASHRAE, and SMACNA Standards and recommended practices, as applicable.

**3.02 PROCEDURES**

- A. Air Systems: Perform the following minimum tests and balancing:
  1. Adjust all air handling systems to provide the required design air quantity to, or through, each component. Adjusting and balancing of all systems shall be conducted during periods of the year approximating maximum seasonal operations, to the extent possible.
  2. Equalizing devices shall be adjusted to provide uniform velocity across the inlet duct side for supply of terminals prior to measuring flow rates.
  3. Flow adjusting, volume control devices shall be used to balance air quantities only, proportioning flow between various terminals comprising system and only to the extent that their adjustments do not create objectionable air motion or sound in excess of specified limits.
  4. Balancing between runs, sub mains, branch mains, and branches shall be accomplished by flow regulating devices at, or in, the divided-flow fitting.

5. Restriction imposed by flow regulating devices in or at terminals shall be minimal. Final measurements of air quantity shall be made after the air terminal has been adjusted to provide the optimum air patterns of diffusions.
  6. Total air system quantities shall be varied by adjustment of fan speeds or axial-flow fan wheel blade pitch. Damper restriction of a system's total flow may be used only for systems with direct-connected fans without adjustable pitch blades, provided system pressure is less than 1/2 inch w.g. and sound level criteria are met.
  7. Where air-measuring systems specified in Section 23 09 00 - Instrumentation and Control for HVAC, are provided, such systems shall be used to measure applicable total system branch duct and terminal airflows herein required.
  8. Except as specifically indicated herein, Pitot tube traverses shall be made of each duct to measure airflow therein. Pitot tubes, associated instruments, traverses, and techniques shall conform to the ASHRAE Handbook, HVAC Applications; and ASHRAE Handbook, HVAC Systems and Equipment.
  9. Pitot tube traverses may be omitted, provided the duct serves only a single room or space and its design volume is less than 2000 cfm. In lieu of Pitot tube traverses, airflow in the duct shall be determined by totaling volume of individual terminals served, measured as specified herein.
  10. Where duct design velocity and air quantity are both less than 1000 fpm/cfm, air quantity may be determined by measurements at terminals served.
  11. Test holes, specified in Section 23 31 00 - HVAC Ducts and Casings, shall be in a straight duct, as far as possible downstream from elbows, bends, take-offs, and other turbulence-generating devices, to optimize reliability of flow measurements.
  12. Measurement of flow rates by means of velocity meters applied to individual terminals, with or without cones or other adapters, shall be used for balancing. Each air terminal shall be tested and adjusted to within 10 percent of design air quantity at final balance. Measurement of air quantities at each type of air terminal (inlet and outlet) shall be determined by the method approved for the balancing agenda. Laboratory tests shall be conducted to prove accuracy of methodology when so directed.
  13. Air motion and distribution shall be as indicated. In addition to air motion measurements, perform one smoke test for each supply air system at a location selected by the Engineer at time of tests to demonstrate the air distribution from air terminals.
  14. Adjustment of automatically operated dampers shall be set to operate as indicated. Controls shall be checked for proper calibration. A list of controls requiring adjustment shall be submitted to the Engineer for review.
- B. Air Conditioning Units: Test air-conditioning unit, including the air-cooled condensing unit and the evaporator coils, as one entity. Check and adjust the system for proper operation under available system cooling load. Test and check the following equipment and operation:
1. Airflow across evaporator coil, cfm;
  2. Evaporator coil face area, square feet;

3. Evaporator coil velocity, fpm;
  4. Evaporator coil entering air, dry-bulb and wet-bulb temperatures;
  5. Evaporator coil leaving air, dry-bulb and wet-bulb temperatures;
  6. Evaporator temperature at coil suction connection;
  7. Amperage to the compressor motor (rated and actual) when operating;
  8. Condenser entering ambient air temperature, dry-bulb;
  9. Fan speed (rpm) and, amperage (rated and actual) of each condenser fan and evaporator fan;
  10. Condenser airflow and temperature rise, all condenser fans operating;
  11. Charged refrigeration system pressure at charging connection; and
  12. Outdoor air temperature, dry-bulb and wet-bulb.
- C. Heat Pumps: Test heat pump, including indoor and outdoor units, as one entity. Check and adjust the system for proper operation under available system cooling and heating loads, in heating and cooling modes. Test and check the following equipment and operations:
1. Airflow across indoor unit coil, cfm;
  2. Coil face area, square feet;
  3. Coil velocity, fpm;
  4. Coil entering air, dry-bulb and wet-bulb temperatures;
  5. Coil leaving air, dry-bulb and wet-bulb temperatures;
  6. Amperage to the compressor motor (rated and actual) when operating.
  7. Outdoor unit coil entering ambient air temperature, dry-bulb;
  8. Fan speed (rpm) and, amperage (rated and actual) of each fan, indoor and outdoor unit;
  9. Outdoor unit airflow and temperature rise and drop, all fans operating;
  10. Charged refrigeration system pressure at charging connection; and
  11. Outdoor air temperature, dry-bulb and wet-bulb.
- D. Electric Duct or Unit Mounted Heating Coil: Perform the following tests of electric heaters under available system heating loads:
1. Airflow across the coil, cfm;
  2. Coil face area, square feet;
  3. Coil velocity, fpm;
  4. Coil entering air temperatures;
  5. Coil leaving air temperatures; and
  6. Amperage to the coil (rated and actual) when operating.
- E. Sound Levels: Perform the following sound tests in accordance with ANSI S1.13, to demonstrate that compliance with sound requirements is satisfied at each selection point included in the reports, as follows:
1. Sound level measurements shall be taken at times when the building is unoccupied, or when activity in surrounding areas and background noise levels in areas tested are at a minimum and relatively free from sudden changes in noise levels.
    - a. Measurements shall be taken with all equipment secured, except that being tested.
    - b. The actual sound levels shall be measured at any point within a room not less than 6 feet from an air terminal (such as fan coil unit, VAV box) or room unit, and not closer than 3 feet from any floor, wall, or ceiling surface.

2. Sound levels shall be measured with a sound meter complying with ANSI S1.4. The "A" scale shall be used to measure over all sound levels. To determine the specified octave band levels, the above sound level meter, set on "C" scale, shall be supplemented by an Octave Band Analyzer complying with ANSI S1.11.

### 3.03 DOCUMENTATION

A. Test Data Sheets: Test data sheets shall be provided in accordance with the following requirements:

1. Test data sheet forms shall be subject to approval and shall be provided for recording measurement readings and data. These forms may be reproduced from samples supplied by the independent testing and balancing agent.
2. Where computers are used for calculations and data printout is included, standard forms may be used, provided that all information required by the standard forms is included. These forms and an explanation of the computer program shall be submitted for approval.
3. For components not included in the test data sheet forms, the data shall be recorded concisely and logically for submittal.
4. Sheets shall be completed by the independent testing and balancing agent, dated with test dates, and signed by the technician performing the work. Prior to final submittal, the test data sheets shall be reviewed and approved by the testing and balancing agent's engineer or manager. Test data sheets shall be typed for final submittal.
5. Spaces on the data sheet, that are not applicable, shall be indicated with an N/A. Design data, that is not known or not available, shall be indicated with an N/K.
6. Readings or data, that are applicable, but not provided for on the data sheet, shall be included and shall be explained under the heading "Remarks."

B. Certified Reports: Three copies of the reports specified herein, covering HVAC system performance, air motion (fpm), and sound pressure levels, shall be submitted prior to final tests and inspection.

1. Instrument records, including types, serial numbers, and dates of calibration of all instruments, shall accompany the final submittal data.
2. Reports shall identify conspicuously items not conforming to Contract requirements, or obvious deficiencies in design and operation.
3. Approved system flow diagram shall be submitted with the test data sheets and report. Flow diagrams shall indicate measured flows, pressures, and temperatures.
4. The reports shall be certified by an independent registered professional engineer who is versed in the field of HVAC balancing and who is not affiliated with any firm involved in

the installation phases of the project. Certification shall include checking of adherence to agenda, of calculations, of procedures, and evaluation of final summaries.

C. System Data: The certified report shall include for each air handling system the following information:

1. Equipment:

a. Installation data:

- 1) Manufacturer and model;
- 2) Size;
- 3) Arrangement, discharge, and class;
- 4) Motor hp, voltage, phase, cycles, and full load amperes; and
- 5) Location and local identification data.

b. Fan recorded test data:

- 1) Airflow (supply, return and/or outside air) cfm;
- 2) Total external static pressure recorded only where total system delivery cannot be checked by measuring velocity in main circuit;
- 3) rpm;
- 4) Motor operating amperes; and
- 5) Motor operating bhp.

c. Air temperature test data:

- 1) Leaving air temperature, dry bulb and wet bulb;
- 2) Entering air temperature, dry bulb and wet bulb; and
- 3) Outdoor air temperature, dry bulb and wet bulb.

2. Duct Systems:

a. Duct air quantities maximum and minimum; main, sub mains, branches, outdoor (outside) air, total air, and exhaust air:

- 1) Duct sizes;
- 2) Number of Pitot tube pressure measurements;
- 3) Sum of velocity measurements (Note: Do not add pressure measurements);
- 4) Average velocity;
- 5) Recorded (test) cfm; and
- 6) Design cfm.

b. Individual air terminals (such as supply diffusers, return/exhaust registers, grills):

- 1) Terminal identification, supply or exhaust, location and number designation;
- 2) Type, size, manufacturer, and catalog identification;
- 3) Applicable factor for application, velocity, area, and designated area;
- 4) Design and recorded velocities - fpm (state "core," "inlet," as applicable);
- 5) Design and recorded quantities - cfm; and
- 6) Deflector vane or diffusion cone settings.

- D. Sound Level Data: The certified report shall record the sound levels, taken at each selected location, as follows:
1. Source of sound and location.
  2. Diagram or description of relationship of sound source to measuring instrument.
  3. "A" scale readings:
    - a. Equipment being tested turned off (ambient); and
    - b. Equipment being tested turned on (operating conditions).
  4. Reading at each specified octave band frequency:
    - a. Equipment being tested turned off (ambient); and
    - b. Equipment being tested turned on (operating conditions).
  5. Graph showing relationship between pressure levels specified and recorded readings.
- E. Equipment Cards: Install at each piece of equipment a "checkout" card showing significant operating temperatures, pressures, amperes, voltages, and brake horsepower. Checkout cards shall be standard 5 inches by 7 inches index cards enclosed in a clear plastic card folder, securely attached to the equipment or to a wall in the immediate area.

### **3.04 FINAL TESTS AND ACCEPTANCE**

- A. Tests shall be performed to demonstrate that capacities and performance of HVAC systems comply with Contract requirements.
1. At the time of final inspection, the Contractor shall recheck, in the presence of the Engineer, random selections of data (air quantities, air motion, and sound levels) recorded in the Certified Report.
  2. Points and areas for recheck shall be selected by the Engineer.
  3. Measurement and test procedures shall be the same as approved for the work forming the basis of the Certified Report.
  4. Selections for recheck (specific plus random), in general, will not exceed 25 percent of the total number tabulated in the report, except that special air systems may require a complete recheck for safety reasons.
- B. If random tests elicit a measured flow deviation of 10 percent or more from, or a sound level of 2 dB or more, greater than, that recorded in the Certified Report listings, at 10 percent or more of the rechecked selections, the report will be automatically rejected. In the event the report is rejected, all systems shall be readjusted and retested, new data recorded, new Certified Reports submitted, and new inspection tests made, all at no additional cost to the District.

- C. Subsequent to any correctional construction work, such as acoustic corrections, measurement shall be made to verify that associated airflow quantities, as previously measured, have not been disrupted.
- D. Following final approval of Certified Reports by the Engineer, the settings of all valves, splitters, dampers, and other adjustment devices shall be permanently marked by the Contractor so that adjustment can be restored if disturbed at any time. Devices shall not be marked until after final acceptance.

**3.05 FIELD SERVICES**

- A. Instruction of District's Personnel: The Testing and Balancing Agency shall instruct the District's personnel in the proper operation, setting, and adjustment of the equipment.
- B. Re-inspection: The Testing and Balancing Agency shall make two return inspection trips to the project, one during a period when actual conditions match heating design conditions and one during a period when actual conditions match air-conditioning design conditions, for the purpose of checking out the entire system (or group of systems). The Testing and Balancing Agency shall make additional adjustments as required during the re-inspection.

**END OF SECTION 23 05 93**