

**SECTION 23 05 93**  
**TESTING, ADJUSTING, AND BALANCING FOR HVAC**

SPEC WRITER NOTES:

1. Use this section only for NCA projects.
2. Delete between // // if not applicable to project. Also delete any other item or paragraph not applicable in the section and renumber the paragraphs.
3. References to pressure in this section are gage pressure unless otherwise noted.
4. When project involves connecting new work to existing systems, designer must evaluate impact on existing system. If balancing work is deemed necessary on the existing system, provide a description of the work involved in the Specification and indicate areas involved on the Drawings.

**PART 1 - GENERAL**

**1.1 DESCRIPTION**

- A. Testing, adjusting, and balancing (TAB) of heating, ventilating and air conditioning (HVAC) systems and plumbing water recirculation. TAB includes the following:
1. Planning TAB procedures.
  2. Reviewing Contract Documents for producing and submitting a report.
  3. Producing and submitting a report summarizing observations from the Contract Documents review.
  4. Producing and submitting a Systems Inspection report.
  5. Producing and submitting a Duct Air Leakage Test Report.
  6. Producing and submitting a Systems Readiness Report.
  7. Balancing and adjusting air and water distribution systems to provide design performance; and testing performance of equipment and automatic controls for the following systems:
    - a. Air Systems
    - b. Hydronic Systems
    - c. Plumbing recirculation systems.
  8. Recording and reporting vibration and sound measurements.
  9. Control Systems verification.
- B. A complete listing of common acronyms and abbreviations are included in Section 23 05 11, COMMON WORK RESULTS FOR HVAC.

## C. Definitions:

1. Basic TAB used in this Section: Testing, Adjusting, and Balancing Chapter of ASHRAE Handbook-HVAC Applications.
2. TAB: Testing, Adjusting, and Balancing; the process of checking and adjusting HVAC systems to meet design objectives and recording and reporting measurements.
3. AABC: Associated Air Balance Council.
4. NEBB: National Environmental Balancing Bureau.
5. SMACNA: Sheet Metal and Air Conditioning Contractors National Association.
6. TABB: Testing, Adjusting and Balancing Bureau.
7. Hydronic Systems: Includes ground source heat pump condenser water.
8. Air Systems: Includes all outside air, supply air, return air, exhaust air, and relief air systems.
9. Flow rate tolerance: The allowable percentage variation, minus to plus, of actual flow rate from values (design) in the contract documents.
10. Out-of-tolerance data: When applied to TAB work this phrase means "a measurement which does not fall within the prescribed range for a specific parameter."
11. Season of maximum heating load: The time of year when the outdoor temperature at the project site remains within plus or minus //20// // // degrees F of the project site's winter outdoor design temperature, throughout the period of TAB data recording.
12. Season of maximum cooling load: The time of year when the outdoor temperature at the project site remains within plus or minus 5 degrees F of the project site's summer outdoor design temperature through the period of TAB data recording.
13. Season 1, Season 2: Depending upon when the project HVAC is completed and ready for TAB, Season 1 is defined, thereby defining Season 2. Season 1 could be the season of maximum heating load, or the season of maximum cooling load.

**1.2 RELATED WORK**

SPEC WRITER NOTE: Retain one of two paragraphs below.

- A. //Section 01 00 01, GENERAL REQUIREMENTS (Major NCA Projects).//
- B. //Section 01 00 02, GENERAL REQUIREMENTS (Minor NCA Projects).//
- C. Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.

- D. Section 01 42 19, REFERENCE STANDARDS.
- E. Section 01 81 13, SUSTAINABLE DESIGN REQUIREMENTS.
- F. //Section 01 91 00, GENERAL COMMISSIONING REQUIREMENTS.//
- G. Section 23 05 11, COMMON WORK RESULTS FOR HVAC: General mechanical requirements and items which are common to more than one section of Division 23.
- H. Section 23 05 41, NOISE AND VIBRATION CONTROL FOR HVAC PIPING AND EQUIPMENT: Noise and Vibration Requirements.
- I. Section 23 07 11, HVAC INSULATION: Piping and Equipment Insulation.
- J. //Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS.//
- K. //Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC: Controls and Instrumentation Settings.//
- L. Section 23 21 23, HYDRONIC PUMPS.
- M. Section 23 31 00, HVAC DUCTS AND CASINGS: Duct Leakage.
- N. Section 23 36 00, AIR TERMINAL UNITS: Terminal Units Performance.
- O. Section 23 81 00, UNITARY HVAC EQUIPMENT.

**1.3 APPLICABLE PUBLICATIONS**

SPEC WRITER NOTE: Make material requirements agree with requirements specified in the referenced Applicable Publications. Verify and update the publication list to that which applies to the project, unless the reference applies to all mechanical systems. Publications that apply to all mechanical systems may not be specifically referenced in the body of the specification, but, shall form a part of this specification.

- A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.
- B. Air Movement and Control Association (AMCA):  
201-2012.....Fans and Systems
- C. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE):  
Latest Edition.....ASHRAE Handbook-HVAC Applications, Testing, Adjusting, and Balancing Chapter and Noise and Vibration Control Chapter  
62.1-2016.....Ventilation for Acceptable Indoor Air Quality  
90.1-2013.....Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings

- D. Associated Air Balance Council (AABC):
  - 2015.....National Standards for Total System Balance, 7th Edition
- E. National Environmental Balancing Bureau (NEBB):
  - 2015.....Procedural Standard for Testing, Adjusting and Balancing of Environmental Systems, 8th Edition
  - 2015.....Procedural Standard for Measurement of Sound and Vibration, 3rd Edition
  - 2014.....Procedural Standards for Whole Building Systems Technical Commissioning for New Construction, 4th Edition
- F. Sheet Metal and Air Conditioning Contractors National Association (SMACNA):
  - 2002.....HVAC Systems Testing, Adjusting and Balancing, 3rd Edition
  - 2006.....HVAC Systems Duct Design, 4th Edition
- G. Testing, Adjusting and Balancing Bureau (TABB):
  - .....Quality Assurance Program

**1.4 SUBMITTALS**

- A. Submittals, including number of required copies, shall be submitted in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.
- B. Information and material submitted under this section shall be marked "SUBMITTED UNDER SECTION 23 05 93, TESTING, ADJUSTING, AND BALANCING FOR HVAC", with applicable paragraph identification.
- C. Manufacturer's Literature and Data including: Full item description and optional features and accessories. Include dimensions, weights, materials, applications, standard compliance, model numbers, size, and capacity.
- D. TAB Report Forms: Use standard TAB contractor's forms approved by //Architect// //Contractor// //COR// //Commissioning Authority//.
- E. Submit names and qualifications of TAB agency and TAB specialists within 60 days after the notice to proceed. Submit information on three recently completed projects and a list of proposed test equipment.
- F. For use by the Contracting Officer's Representative (COR) staff, submit one complete set of applicable AABC, NEBB, or TABB/SMACNA publications that will be the basis of TAB work.

- G. Submit the following for Review and Approval:
1. Contract Documents Review Report //within //45// //60// //90// days for conventional design projects// //and within //45// //60// //90// days for design-build projects// after the system layout on air, and water is completed by the Contractor.
  2. Systems Inspection Report on equipment and installation for conformance with design.
  3. Duct Air Leakage Test Report.
  4. Systems Readiness Report.
  5. Intermediate and Final Certified TAB reports including flow balance and adjustments, performance tests, vibration tests, and sound tests.
  6. Include in final reports uncorrected installation deficiencies noted during TAB and applicable explanatory comments on test results that differ from design requirements.
  7. Strategies and Procedures Plan: Within 60 days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in paragraph, PREPARATION in Part 3.
  8. Sample report forms.
- H. Prior to request for Final Inspection, submit completed Test and Balance report for the area.
- I. Instrument calibration reports, to include the following:
1. Instrument type and make.
  2. Serial number.
  3. Application.
  4. Dates of use.
  5. Dates of calibration.
- J. //Completed System Readiness Checklist provided by the Commissioning Agent and completed by the contractor, signed by a qualified technician and dated on the date of completion, in accordance with the requirements of Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS.//

#### **1.5 QUALITY ASSURANCE**

- A. Refer to paragraphs QUALITY ASSURANCE and SUBMITTALS in Section 23 05 11, COMMON WORK RESULTS FOR HVAC.
- B. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, "Air Balancing."
- C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, "System Balancing."

## D. Qualifications:

1. TAB Agency: The TAB agency shall be a subcontractor of the General Contractor and shall report to and be paid by the General Contractor.
2. The TAB agency shall be either a certified member of AABC or certified by the NEBB, SMACNA, or TABB to perform TAB service for HVAC, water balancing, and vibration and sound testing of equipment. The certification shall be maintained for the entire duration of duties specified herein. If, for any reason, the agency loses subject certification during this period, the General Contractor shall immediately notify the COR and submit another TAB firm for approval. Any agency that has been the subject of disciplinary action by either the AABC, NEBB, or TABB within the five years preceding Contract Award shall not be eligible to perform any work related to the TAB. All work performed in this Section and in other related Sections by the TAB agency shall be considered invalid if the TAB agency loses its certification prior to Contract completion, and the successor agency's review shows unsatisfactory work performed by the predecessor agency.
3. TAB Specialist: The TAB specialist shall be either a member of AABC or an experienced technician of the agency certified by NEBB or TABB. The certification shall be maintained for the entire duration of duties specified herein. If, for any reason, the Specialist loses subject certification during this period, the General Contractor shall immediately notify the COR and submit another TAB Specialist for approval. Any individual that has been the subject of disciplinary action by either the AABC, NEBB, or TABB within the five years preceding Contract Award shall not be eligible to perform any duties related to the HVAC systems, including TAB. All work specified in this Section and in other related Sections performed by the TAB specialist shall be considered invalid if the TAB Specialist loses its certification prior to Contract completion and must be performed by an approved successor.
4. TAB Specialist shall be identified by the General Contractor within 60 days after the notice to proceed. The TAB specialist will be coordinating, scheduling and reporting all TAB work and related activities and will provide necessary information as required by the COR. The responsibilities would specifically include:

- a. Directly supervising all TAB work.
  - b. Signing the TAB reports that bear the seal of the TAB standard.  
The reports shall be accompanied by report forms and schematic drawings required by the TAB standard, AABC, NEBB, or TABB.
  - c. Following all TAB work through its satisfactory completion.
  - d. Providing final markings of settings of all HVAC adjustment devices.
  - e. Permanently marking location of duct test ports.
5. All TAB technicians performing TAB work shall be experienced and must have done satisfactory work on a minimum of 3 projects comparable in size and complexity to this project. Qualifications must be certified by the TAB agency in writing.
- E. Test Equipment Criteria: The instrumentation shall meet the accuracy and calibration requirements established by AABC National Standards, TABB/SMACNA International Standards, or by NEBB Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems and instrument manufacturer. Provide calibration history of the instruments to be used for test and balance purpose.
- F. TAB Criteria:
- 1. One or more of the applicable AABC, NEBB, or SMACNA publications, supplemented by ASHRAE Handbook-HVAC Applications, Testing, Adjusting, and Balancing Chapter, and requirements stated herein shall be the basis for planning, procedures, and reports.
  - 2. Flow rate tolerance: Following tolerances are allowed. For tolerances not mentioned herein follow ASHRAE Handbook-HVAC Applications, Testing, Adjusting, and Balancing Chapter, as a guideline. Air Filter resistance during tests, artificially imposed if necessary, shall be at least 90 percent of final values for all filters.
    - a. Air handling unit and all other fans, cubic meters/min (cubic feet per minute): Minus 0 percent to plus 10 percent.
    - b. Air terminal units (maximum values): Minus 2 percent to plus 10 percent.
    - c. Outside air: 0 percent to plus 10 percent.
    - d. Exhaust air: 0 to 10 percent more than design.
    - e. Individual room air outlets and inlets, and air flow rates not mentioned above: Minus 2 percent to plus 10 percent except if the

air to a space is 100 CFM or less the tolerance would be 0 to plus 5 percent.

- f. Condenser water pumps: 0 percent to plus 5 percent.
- 3. Systems shall be adjusted for energy efficient operation as described in PART 3.
- 4. When field TAB work begins typical TAB procedures and results shall be demonstrated to the COR for one air distribution system (including all fans, three terminal units and three rooms) and one hydronic system (pumps and three coils).
- G. TAB Conference: Meet with //Architect// //Contractor// //COR// //Commissioning Authority// on approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Require the participation of the TAB field supervisor and technicians. Provide seven days' advance notice of scheduled meeting time and location. The following shall be the agenda items for the TAB conference:
  - 1. The Contract Documents examination report.
  - 2. The TAB plan.
  - 3. Coordination and cooperation of trades and subcontractors.
  - 4. Coordination of documentation and communication flow.

#### **1.6 PROJECT CONDITIONS**

- A. //Full Occupancy: Site and existing building will be occupied during entire TAB period. Cooperate with Government during TAB operations to minimize conflicts with operations.//
- B. //Partial Occupancy: Completed areas of building may be occupied before Substantial Completion. Cooperate with Government during TAB operations to minimize conflicts with operations.//

#### **1.7 COORDINATION**

- A. Notice: Provide ten calendar days' advance notice to COR for each test. Include scheduled test dates and times.
- B. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

### **PART 2 - PRODUCTS**

#### **2.1 PLUGS**

- A. Provide plastic plugs to seal holes drilled in ductwork for test purposes.

**2.2 INSULATION REPAIR MATERIAL**

- A. See Section 23 07 11, HVAC PLANT INSULATION. Provide for repair of insulation removed or damaged for TAB work.

**PART 3 - EXECUTION****3.1 GENERAL**

- A. Refer to TAB Criteria in paragraph QUALITY ASSURANCE.
- B. Obtain applicable contract documents and copies of approved submittals for HVAC equipment and automatic control systems.

**3.2 CONTRACT DOCUMENTS REVIEW REPORT**

- A. The TAB Specialist shall review the Contract Plans and specifications and advise the COR of any design deficiencies that would preclude proper TAB of systems and equipment or prevent the HVAC systems from effectively operating in accordance with the sequence of operation specified or prevent the effective and accurate TAB of the system. The TAB Specialist shall provide a report individually listing each deficiency and the corresponding proposed corrective action necessary for proper system operation.

**3.3 EXAMINATION**

- A. Examine systems for installed 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 accessible.
- B. Coordinate with the COR the examination of ceiling plenums used for supply, return, or relief air to verify that they meet the leakage class of connected ducts as scheduled on drawings and are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.
- C. Examine equipment performance data including fan and pump curves.
  - 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 or in SMACNA's "HVAC Systems Duct Design." Compare results with the design data and installed conditions.

- D. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.
- E. Examine test reports specified in individual system and equipment Sections.
- F. Examine HVAC equipment and filters and verify that bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.
- G. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.
- H. Examine strainers. Verify that startup screens are replaced by permanent screens with indicated perforations.
- I. Examine three-way valves for proper installation for their intended function of diverting or mixing fluid flows.
- J. Examine heat-transfer coils for correct piping connections and for clean and straight fins.
- K. Examine system pumps to ensure absence of entrained air in the suction piping.
- L. Examine operating safety interlocks and controls on HVAC equipment.
- M. Report deficiencies discovered before and during performance of TAB procedures to COR. Record default set points.

#### **3.4 SYSTEMS INSPECTION REPORT**

- A. Inspect equipment and installation for conformance with design.
- B. The inspection and report is to be done after air distribution equipment is on site and duct installation has begun, but well in advance of performance testing and balancing work. The purpose of the inspection is to identify and report deviations from design and ensure that systems will be ready for TAB at the appropriate time.
- C. Reports: Follow check list format developed by AABC, NEBB, TABB, or SMACNA, supplemented by narrative comments, with emphasis on air handling units and fans. Check for conformance with submittals. Verify that diffuser and register sizes are correct. Check air terminal unit installation including their duct sizes and routing.

#### **3.5 PREPARATION**

- A. Prepare a TAB plan that includes strategies and step-by-step procedures.

- B. Complete system-readiness checks and prepare reports. Verify the following:
1. Permanent electrical-power wiring is complete.
  2. Hydronic systems are filled, clean, and free of air.
  3. Automatic temperature-control systems are operational.
  4. Equipment and duct access doors are securely closed.
  5. Balance, smoke and fire dampers are open.
  6. Isolating and balancing valves are open to the proper setpoint and control valves are operational.
  7. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
  8. Windows and doors can be closed so indicated conditions for system operations can be met.

### **3.6 DUCT AIR LEAKAGE TEST REPORT**

- A. See paragraph DUCT LEAKAGE TESTS AND REPAIR in Section 23 31 00, HVAC DUCTS AND CASINGS for TAB agency's role and responsibilities in witnessing, recording and reporting of deficiencies.
- B. Inspect each System to ensure that it is complete including installation and operation of controls.
- C. Verify that all items such as ductwork piping, ports, terminals, connectors, etc., that is required for TAB are installed. Provide a report to the COR.

### **3.7 PRELIMINARY TAB REPORTS**

- A. Submit an intermediate report for minimum of 50 percent of systems and equipment tested and balanced to establish satisfactory test results.
- B. The TAB contractor shall provide raw data immediately in writing to the COR if there is a problem in achieving intended results before submitting a formal report.
- C. If over 20 percent of readings in the intermediate report fall outside the acceptable range, the TAB report shall be considered invalid and all contract TAB work shall be repeated and re-submitted for approval.
- D. Do not proceed with the remaining systems until intermediate report is approved by the COR.

### **3.8 FINAL TAB REPORT**

- A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
  2. Include a list of instruments used for procedures, along with proof of calibration.
- B. 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; do not include Shop Drawings and product data.
- C. General Report Data: In addition to form titles and entries, include the following data:
1. Title page.
  2. Name and address of the TAB contractor.
  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 supervisor 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:
    - a. Design or indicated versus final performance.
    - b. Notable characteristics of systems.
    - c. Description of system operation sequence if it varies from the Contract Documents.
  12. Nomenclature sheets for each item of equipment.
  13. Data for terminal units, including manufacturer's name, type, size, and fittings.
  14. Notes to explain why certain final data in the body of reports vary from indicated values.
  15. Test conditions for fans and pump performance forms including the following:
    - a. Settings for outdoor-, return-, and exhaust-air dampers.

- b. Conditions of filters.
  - c. Cooling coil, wet- and dry-bulb conditions.
  - d. Face and bypass damper settings at coils.
  - e. Fan drive settings including settings and percentage of maximum pitch diameter.
  - f. Settings for supply-air, static-pressure controller.
  - g. Other system operating conditions that affect performance.
- D. Coil Measurements:
- 1. Entering and leaving dry bulb and wet bulb temperatures shall be determined using a minimum of 9 measurements taken in a grid pattern and in accordance with AABC.
  - 2. Along with the TAB report, submit part-load coil performance data from the coil manufacturer and use the data to verify performance in compliance with AABC.
- E. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:
- 1. Quantities of outdoor, supply, return, and exhaust airflows.
  - 2. Water and steam flow rates.
  - 3. Duct, outlet, and inlet sizes.
  - 4. Pipe and valve sizes and locations.
  - 5. Terminal units.
  - 6. Balancing stations.
  - 7. Position of balancing devices.
- F. Ambient Temperatures: On each TAB report form, record the outdoor and space's indoor ambient wet bulb and dry bulb temperature ranges.
- G. Air Handling Unit and Energy Recovery Unit Test Reports: For air handling units and energy recovery units with coils and/or heat exchangers, include the following:
- 1. Unit Data:
    - 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 mm (inches), and bore.

- i. Center-to-center dimensions of sheave, and amount of adjustments in mm (inches).
    - j. Number, make, and size of belts.
    - k. Number, type, and size of filters.
  2. Motor Data:
    - a. Motor make, and frame type and size.
    - b. Horsepower and rpm.
    - c. Volts, phase, and hertz.
    - d. Full-load amperage and service factor.
    - e. Sheave make, size in mm (inches), and bore.
    - f. Center-to-center dimensions of sheave, and amount of adjustments in mm (inches).
  3. Test Data (Indicated and Actual Measured Values):
    - a. Total supply air flow rate in L/s (cfm).
    - b. Total system static pressure in Pa (inch WG).
    - c. Fan rpm.
    - d. Discharge static pressure in Pa (inch WG).
    - e. Filter static-pressure differential in Pa (inch WG).
    - f. Preheat-coil static-pressure differential in Pa (inch WG).
    - g. Cooling-coil static-pressure differential in Pa (inch WG).
    - h. Heating-coil static-pressure differential in Pa (inch WG).
    - i. Outdoor airflow in L/s (cfm).
    - j. Return airflow in L/s (cfm).
    - k. Outdoor-air damper position.
    - l. Return-air damper position.
    - m. Vortex damper position.
- H. Apparatus-Coil or Heat Exchanger or Energy Wheel Test Reports:
  1. Coil Data:
    - a. System identification.
    - b. Location.
    - c. Coil type, or heat exchanger type, or energy recovery device type.
    - d. Number of rows for coils.
    - e. Fin spacing in fins per mm (inch) o.c. for coils.
    - f. Make and model number.
    - g. Face area in sq. m (sq. ft.) for coils and wheels.
    - h. Tube size in DN (NPS) for coils.
    - i. Tube and fin materials for coils.

- j. Circuiting arrangement for coils.
2. Test Data (Indicated and Actual Measured Values):
- a. Air flow rate in L/s (cfm).
  - b. Average face velocity in m/s (fpm) across coil, and for air handler cross sectional area for heat pipes and across each active portion of wheels.
  - c. Air pressure drop in Pa (inch WG) for each air path.
  - d. Outdoor-air, wet- and dry-bulb temperatures in degrees C (degrees F).
  - e. Return-air, wet- and dry-bulb temperatures in degrees C (degrees F).
  - f. Entering-air, wet- and dry-bulb temperatures in degrees C (degrees F).
  - g. Leaving-air, wet- and dry-bulb temperatures in degrees C (degrees F).
  - h. Water flow rate in L/s gpm for coils.
  - i. Water pressure differential in feet of head or kPa (psig) for coils.
  - j. Entering-water temperature in degrees C (degrees F) for coils.
  - k. Leaving-water temperature in degrees C (degrees F) for coils.
  - l. Refrigerant expansion valve and refrigerant types.
  - m. Refrigerant suction pressure in kPa (psig).
  - n. Refrigerant suction temperature in degrees C (degrees F).
  - o. Inlet steam pressure in kPa (psig).
- I. Gas- and Oil-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:
- 1. Unit Data:
    - a. System identification.
    - b. Location.
    - c. Make and type.
    - d. Model number and unit size.
    - e. Manufacturer's serial number.
    - f. Fuel type in input data.
    - g. Output capacity in kW (Btu/h).
    - h. Ignition type.
    - i. Burner-control types.
    - j. Motor horsepower and rpm.

- k. Motor volts, phase, and hertz.
  - l. Motor full-load amperage and service factor.
  - m. Sheave make, size in mm (inches), and bore, for each sheave.
  - n. Center-to-center dimensions of sheaves, and amount of adjustments in mm (inches).
2. Test Data (Indicated and Actual Measured Values):
- a. Total air flow rate in L/s (cfm).
  - b. Entering-air temperature in degrees C (degrees F) for each stage of heating or if modulating then at a minimum of full load and a minimum of two part load points.
  - c. Leaving-air temperature in degrees C (degrees F) for each stage of heating or if modulating then at a minimum of full load and a minimum of two part load points.
  - d. Entering-air static pressure in Pa (inch WG).
  - e. Leaving-air static pressure in Pa (inch WG).
  - f. Air static-pressure differential in Pa (inch WG).
  - g. Low-fire fuel input in kW (Btu/h) or fire input at each stage if multi-stage or if modulating then at a minimum of full load and two part load points
  - h. High-fire fuel input in kW (Btu/h).
  - i. Manifold pressure in kPa (psig).
  - j. High-temperature-limit setting in degrees C (degrees F).
  - k. Operating set point in kW (Btu/h).
  - l. Motor voltage at each connection.
  - m. Motor amperage for each phase.
  - n. Heating value of fuel in kW (Btu/h).
- J. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air handling units, include the following:
- 1. Unit Data:
    - a. System identification.
    - b. Location.
    - c. Coil identification.
    - d. Capacity in kW (Btu/h).
    - e. Number of stages.
    - f. Connected volts, phase, and hertz.
    - g. Rated amperage.
    - h. Air flow rate in L/s (cfm).

- i. Face area in sq. m (sq. ft.).
- j. Minimum face velocity in m/s (fpm).
2. Test Data (Indicated and Actual Measured Values):
  - a. Heat output in kW (Btu/h).
  - b. Air flow rate in L/s (cfm).
  - c. Air velocity in m/s (fpm).
  - d. Entering-air temperature in degrees C (degrees F) for each stage of heating or if modulating then at a minimum of full load and a minimum of two part load points.
  - e. Leaving-air temperature in degrees C (degrees F) for each stage of heating or if modulating then at a minimum of full load and a minimum of two part load points.
  - f. Voltage at each connection.
  - g. Amperage for each phase.
- K. Fan Test Reports: For supply, return, and exhaust fans, include the following:
  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 mm (inches), and bore for each sheave.
    - h. Center-to-center dimensions of sheaves, and amount of adjustments in mm (inches).
  2. Motor Data:
    - a. Motor make, and frame type and size.
    - b. Horsepower and rpm.
    - c. Volts, phase, and hertz.
    - d. Full-load amperage and service factor.
    - e. Sheave make, size in mm (inches), and bore.
    - f. Center-to-center dimensions of sheaves, and amount of adjustments in mm (inches).
    - g. Number, make, and size of belts.
  3. Test Data (Indicated and Actual Measured Values):
    - a. Total airflow rate in L/s (cfm).
    - b. Total system static pressure in Pa (inch WG).

- c. Fan rpm.
  - d. Discharge static pressure in Pa (inch WG).
  - e. Suction static pressure in Pa (inch WG).
- L. Round, Flat-Oval, and Rectangular 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 degrees C (degrees F).
    - d. Duct static pressure in Pa (inch WG).
    - e. Duct width in mm (inches).
    - f. Duct height in mm (inches).
    - g. Indicated air flow rate in L/s (cfm).
    - h. Indicated velocity in m/s (fpm).
    - i. Actual measured air flow rate in L/s (cfm).
    - j. Actual measured average velocity in m/s (fpm).
    - k. Barometric pressure in psig (Pa).
- M. Air Terminal Device Reports:
- 1. Unit Data:
    - a. System and air handling unit identification.
    - b. Location and zone.
    - c. Apparatus used for test.
    - d. Area served.
    - e. Make.
    - f. Number or mark from system diagram.
    - g. Type and model number.
    - h. Size.
    - i. Effective area of air path in sq. m (sq. ft.).
    - j. Effective area of coil in sq. m (sq. ft.).
  - 2. Test Data (Indicated and Actual Measured Values):
    - a. Air flow rate in L/s (cfm).
    - b. Air velocity in m/s (fpm).
    - c. As needed, preliminary air flow rate in L/s (cfm).
    - d. As needed, preliminary velocity in m/s (fpm).
    - e. Final air flow rate in L/s (cfm).
    - f. Final velocity in m/s (fpm).
    - g. Space temperature in degrees C (degrees F).

- N. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:
1. Unit Data:
    - a. System and air handling unit identification.
    - b. Location and zone.
    - c. Room or riser served.
    - d. Coil make and size.
    - e. Flowmeter type.
  2. Test Data (Indicated and Actual Measured Values):
    - a. Air flow rate in L/s (cfm).
    - b. Entering-water temperature in degrees C (degrees F).
    - c. Leaving-water temperature in degrees C (degrees F).
    - d. Water pressure drop in feet of head or kPa (psig).
    - e. Entering-air temperature in degrees C (degrees F).
    - f. Leaving-air temperature in degrees C (degrees F) degrees C (degrees F).
- O. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:
1. Unit Data:
    - a. Unit identification.
    - b. Location.
    - c. Service.
    - d. Make and size.
    - e. Model number and serial number.
    - f. Water flow rate in L/s (gpm).
    - g. Water pressure differential in feet of head or kPa (psig).
    - h. Required net positive suction head in feet of head or kPa (psig).
    - i. Pump rpm.
    - j. Impeller diameter in mm (inches) from shop drawing submittal or name plate.
    - k. Motor make and frame size.
    - l. Motor horsepower and rpm.
    - m. Voltage at each connection.
    - n. Amperage for each phase.
    - o. Full-load amperage and service factor.
    - p. Seal type.
  2. Test Data (Indicated and Actual Measured Values):
    - a. Static head in feet of head or kPa (psig).

- b. Pump shutoff pressure in feet of head or kPa (psig).
- c. Calculated impeller size in mm (inches).
- d. Full-open flow rate in L/s (gpm).
- e. Full-open pressure in feet of head or kPa (psig).
- f. Final discharge pressure in feet of head or kPa (psig).
- g. Final suction pressure in feet of head or kPa (psig).
- h. Final total pressure in feet of head or kPa (psig).
- i. Final water flow rate in L/s (gpm).
- j. Voltage at each connection.
- k. Amperage for each phase.

### 3.9 TAB PROCEDURES

- A. TAB shall be performed in accordance with the requirement of the Standard under which TAB agency is certified by either AABC or NEBB.
- B. General: During TAB all related system components shall be in full operation. Fan and pump rotation, motor loads and equipment vibration shall be checked and corrected as necessary before proceeding with TAB. Set controls and/or block off parts of distribution systems to simulate design operation of variable volume air or water systems for test and balance work.
- C. Coordinate TAB procedures with any phased construction completion requirements for the project. Provide TAB reports for each phase of the project prior to partial final inspections of each phase of the project.
- D. Allow sufficient time in construction schedule for TAB and submission of all reports for an organized and timely correction of deficiencies.
- E. Timing of TAB work:
  - 1. Season 1 TAB Field Work: When the ambient temperature is within Season 1 limits, accomplish Season 1 TAB field work.
  - 2. Prerequisite HVAC Work Check Out List For Season 2 and Advanced Notice For Season 2 TAB Field Work: Within 150 calendar days after date of the commencement of the Season 1 TAB field work, submit the Season 2 prerequisite HVAC work check out list certified as complete and submit advance notice of commencement of Season 2 TAB field work.
  - 3. Season 2 TAB Field Work: Within 180 calendar days after date of commencement of the Season 2 limits, accomplish Season 2 TAB field work.

SPEC WRITER NOTE: Edit the following list to include all air devices on project which require balancing.

- F. Air Balance and Equipment Test: Include air handling units, fans, terminal units, fan coil units, room diffusers/outlets/inlets.
1. Make all measurements under conditions that will be present when system is in use. Make rest room exhaust airflow measurements after system has been in operation and doors have been closed for 10 minutes.
  2. Check condensate drains for proper connections and functioning.
  3. Check for proper sealing of air handling unit components.
  4. Verify that air duct system is sealed as specified.
  5. Artificially load air filters by partial blanking to produce air static pressure drop of at least 90 percent of the design final pressure drop. If no dirty filter drop is specified allow 1 inch WG.
  6. Adjust fan speeds to provide design air flow. V-belt drives, including fixed pitch pulley requirements, are specified in Section 23 05 11, COMMON WORK RESULTS FOR HVAC.
  7. Test and balance systems in all specified modes of operation, including variable volume, economizer, and fire emergency modes. Verify that dampers and other HVAC controls function properly.
  8. Variable air volume (VAV) systems:
    - a. Develop a plan to simulate diversity.
    - b. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the supply fan that supplies the terminal units, place a selected number of terminal units at a minimum set-point airflow with the remainder at maximum-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.
    - c. //Coordinate TAB, including system volumetric controls, with Section 23 09 23, DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC.//
    - d. Section 23 36 00, AIR TERMINAL UNITS, specifies that maximum and minimum flow rates for air terminal units (ATU) be factory set. Check and readjust ATU flow rates if necessary. Balance air distribution from ATU on full cooling maximum scheduled cubic meters per minute (cubic feet per minute). Reset room thermostats

and check ATU operation from maximum to minimum cooling, to the heating mode, and back to cooling. Record and report the heating coil leaving air temperature when the ATU is in the maximum heating mode.

9. Record final measurements for air handling equipment performance data sheets.
10. 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 full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

SPEC WRITER NOTE: Edit the following list to include all hydronic devices on project which require balancing.

- G. Water Balance and Equipment Test: Include circulating pumps and coils:
1. Check liquid level in expansion tank.
  2. Check makeup water-station pressure gage for adequate pressure for highest vent and at highest point of system.
  3. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
  4. Check air vents for a forceful liquid flow exiting from vents when manually operated.
  5. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size. Include information in report.
    - a. If impeller sizes must be adjusted to achieve pump performance, obtain approval from COR and comply with requirements in Section 23 21 23, HYDRONIC PUMPS.
  6. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual measured amperage exceeds motor nameplate amperage.
  7. Adjust flow rates for equipment. Set coils to values on equipment submittals, if different from values on contract drawings.

8. Record final measurements for hydronic equipment on performance data sheets. Include entering and leaving water temperatures for coils. Include entering and leaving air temperatures (DB/WB for cooling coils) for air handling units and reheat coils. Make air and water temperature measurements at the same time.

### **3.10 VERIFICATION AND ALTERNATE SEASON TESTS**

- A. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.
- B. Seasonal Periods:
  1. If initial TAB procedures were performed during season of maximum heating load or season of maximum cooling load, perform additional TAB during Season 2, season of maximum heating load or season of maximum cooling load as specified in this section.
  2. If initial TAB procedures were not performed during season of maximum heating load and season of maximum cooling load, perform additional TAB during season of maximum heating load and season of maximum cooling load.

### **3.11 VIBRATION TESTING**

- A. Furnish instruments and perform vibration measurements as specified in Section 23 05 41, NOISE AND VIBRATION CONTROL FOR HVAC PIPING AND EQUIPMENT. Field vibration balancing is specified in Section 23 05 11, COMMON WORK RESULTS FOR HVAC. Provide measurements for all rotating HVAC equipment of 373 watts (1/2 horsepower) and greater, including rotary and screw compressors, pumps, fans and motors.
- B. Record initial measurements for each unit of equipment on test forms and submit a report to the COR. Where vibration readings exceed the allowable tolerance Contractor shall be directed to correct the problem. The TAB agency shall verify that the corrections are done and submit a final report to the COR.

### **3.12 SOUND TESTING**

- A. Perform and record required sound measurements in accordance with paragraph QUALITY ASSURANCE in Section 23 05 41, NOISE AND VIBRATION CONTROL FOR HVAC PIPING AND EQUIPMENT.
- B. Take measurements with a calibrated sound level meter and octave band analyzer of the accuracy required by AABC, NEBB, or TABB.
- C. Sound reference levels, formulas and coefficients shall be according to ASHRAE Handbook-HVAC Applications, Noise and Vibration Control Chapter.

D. Determine compliance with specifications as follows:

1. When sound pressure levels are specified, including the NC Criteria in Section 23 05 41, NOISE AND VIBRATION CONTROL FOR HVAC PIPING AND EQUIPMENT:

- a. Reduce the background noise as much as possible by shutting off unrelated audible equipment.
- b. Measure octave band sound pressure levels with specified equipment "off."
- c. Measure octave band sound pressure levels with specified equipment "on."
- d. Use the DIFFERENCE in corresponding readings to determine the sound pressure due to equipment.

|             |    |   |   |   |   |        |            |
|-------------|----|---|---|---|---|--------|------------|
| DIFFERENCE: | 0  | 1 | 2 | 3 | 4 | 5 to 9 | 10 or More |
| FACTOR:     | 10 | 7 | 4 | 3 | 2 | 1      | 0          |

Note: Sound pressure level due to equipment equals sound pressure level with equipment "on" minus FACTOR.

- e. Plot octave bands of sound pressure level due to equipment for typical rooms on a graph which also shows noise criteria (NC) curves.

2. When sound power levels are specified:

- a. Perform steps 1.a. thru 1.d., as above.
- b. For indoor equipment: Determine room attenuating effect, i.e., difference between sound power level and sound pressure level. Determined sound power level will be the sum of sound pressure level due to equipment plus the room attenuating effect.
- c. For outdoor equipment: Use directivity factor and distance from noise source to determine distance factor, i.e., difference between sound power level and sound pressure level. Measured sound power level will be the sum of sound pressure level due to equipment plus the distance factor. Use //9 meters (30 feet)// //12 meters (40 feet)// //15 meters (50 feet)// for sound level location.

E. Where measured sound levels exceed specified level, the installing contractor or equipment manufacturer shall take remedial action approved by the COR and the necessary sound tests shall be repeated.

### 3.13 MARKING OF SETTINGS

A. Following approval of Final TAB Report, the setting of all HVAC adjustment devices including valves, splitters and dampers shall be

permanently marked by the TAB Specialist so that adjustment can be restored if disturbed at any time. Style and colors used for markings shall be coordinated with the COR.

### **3.14 IDENTIFICATION OF TEST PORTS**

- A. The TAB Specialist shall 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.

### **3.15 //COMMISSIONING**

- A. Provide commissioning documentation in accordance with the requirements of Section 23 08 00, COMMISSIONING OF HVAC SYSTEMS.
- B. Components provided under this section of the specification will be tested as part of a larger system.//

- - - E N D - - -