

SECTION 15990 – “TESTING, ADJUSTING AND BALANCING”

- 1.0 Refer to Section 15010 for system commissioning requirements. The A/E shall specify that the Mechanical (HVAC, and Plumbing) Contractors, Controls Contractor and Balancing Contractor shall review the Commissioning Plan, support all commissioning efforts and value for same as part of their construction costs..
- 2.0 The A/E shall specify a complete and comprehensive total-system initial and final balance process that includes testing, adjusting, and balancing of environmental, piping, controls, and other systems to produce the design objectives. Initial and final air and water balance of mechanical systems shall be provided and be the responsibility of the mechanical contractor per the standards and process outlined below. The initial balance process serves as the quality control function to insure systems are performing to the specified design intent before the final system balancing. A separate final balance process shall be provided. The University reserves the option, at any point in the construction process, to hire an independent Testing and Balancing Organization to review the mechanical contractor’s (and the associated testing and balancing agency's) performance, balancing results and general adherence to the project specifications and schedule. The Mechanical Contractor will incur penalties if the balancing efforts are found to be deficient. Coordinate with the Office of the University Engineer for penalties to be specified. Any changes to any system will require rebalancing of affected areas, possibly entire system.
- 3.0 The Testing and Balancing process shall be specified to meet the Associated Air Balance Council (AABC) or National Environmental Balancing Bureau (NEBB) Standards latest editions. All balance work provided must be performed by a Testing and Balancing Contractor who is an approved member of AABC and/or NEBB. The Testing and Balancing Contractor shall provide all required pre-construction plan checks and reviews; shall test, adjust, and balance the air and water system for the project; and shall submit completed reports, analysis, and verification data showing system performance that satisfies contract requirements. Project specifications shall require that only certified engineers and technicians be allowed to test and balance systems in buildings requiring American Association for Accreditation of Laboratory Animal Care (AAALAC) certification.
- 4.0 *Balancing of Phased Projects*
 - A. Projects often constructed and occupied in multiple phases. The Testing and Balancing process specified shall address the requirements of interim balancing to support partial occupancy of buildings. The health and safety of occupants and the environmental conditions must be suitable for continuous operation at all phases during construction.
 - B. Mechanical systems may require complete or zone balancing at the end of each phase. Once fully occupied, entire systems may require re-verification

to ensure that later phases have not created deficiencies in early ones. Multiple drive assemblies may be required for fans. Follow-up Testing and Balancing work may also be required during premium time to avoid disruption in research functions.

- C. The completion of Testing and Balancing services seldom occurs smoothly because of construction problems and occupancy functions. The A/E's task is to define a generalized Testing and Balancing procedure that fully supports the phasing and clearly ties down the full scope of work at bid time. All cost associated with Testing and Balancing services through the completion of building occupancy should be included at bid time.
- 5.0 The following paragraphs describe the responsibilities of the Mechanical Contractor(s) for the initial operation of the mechanical systems. The A/E shall assure that the contract documents accurately reflect the following:
- A. Operate the systems as required for the completion of all testing, balancing and adjusting work as directed by the TAB Contractor.
 - B. Make any changes in pulleys, belts and dampers and/or provide any additional dampers to air systems or provide additional balancing devices to air and water systems as directed by the TAB Contractor at any stage of construction. Provide documentation to the University of Pennsylvania for records purposes.
 - C. Operate the installed systems demonstrating functionality of the systems specified at his own expense and for a sufficient length of time to demonstrate the sequence of operation and to definitely determine whether the system as a whole is performing in accordance with the drawings and specifications. Heating and cooling equipment shall be operated during the appropriate seasons for the associated equipment.
 - D. Perform additional work as described further herein and cooperate completely with the TAB Contractor, furnishing all other labor, materials and equipment necessary to assure proper completion of all testing, balancing and adjusting work.
 - E. Provide cleaning and flushing of all piped systems. Clean strainers. Provide final strainer baskets.
 - F. Replace HVAC system filters until building construction is complete and building is turned over to the University of Pennsylvania.
 - G. Vibrations balance all rotating equipment. Provide final balance documents.

- H. Evacuate air from all water systems.
 - I. Support commissioning efforts outlined in the Commissioning Plan.
- 6.0 The following paragraphs describe the responsibilities of the Testing and Balancing Organization for the initial and final balance of the mechanical systems. The A/E shall assure the Contract Documents accurately reflect the following:
- A. The Mechanical Contractor shall engage, a Qualified Testing and Balancing Organization whose primary work is the initial and final Testing, Adjusting and Balancing (TAB) of HVAC and piping systems following procedures prescribed by a recognized agency such as the Associated Air Balance Council (AABC) or the National Environmental Balancing Bureau (NEBB).
 - B. Personnel performing the Testing, Adjusting and Balancing work will be full time employees of the TAB Contractor and shall be thoroughly trained and experienced in the Testing, Balancing and Adjusting of heating, ventilating and air conditioning systems. TAB personnel will include at least one (1) qualified testing and balancing Engineer/Supervisor for directing and supervising the work who has satisfactorily passed the requirements prescribed by a recognized agency such as the AABC or NEBB, and whose qualifications are satisfactory to the Engineer and Architect.
 - C. The scope of work of the TAB Contractor shall include but not be limited to the following:
 - 1. Ascertaining that all Automatic Control and Monitoring work is completed and operating properly in accordance with the Sequence of Operation specification.
 - 2. Initial and final testing, balancing and adjusting of all portions of all air supply, return and exhaust systems.
 - 3. Initial and final testing, balancing and adjusting of all portions of all piping systems.
 - 4. A full report by the TAB Contractor to the Design Engineer on each phase of this work as outlined below.
 - 5. Support Commissioning efforts as outlined in the Commissioning Plan.
 - D. The specification shall reflect the following general procedures by TAB Contractor:

1. Report to and review the work required in conjunction with the Commissioning Plan (as described in Section 15010) with the Design Engineer before beginning field balance work.
 2. Cooperate with the Design Engineer and the Mechanical Contractor(s) to effect smooth coordination of balancing work with the job schedule.
 3. Be responsible for getting the various systems into proper operation, including the Automatic Control and Monitoring Systems. The Mechanical Contractor(s) and all of his sub-contractors, particularly the Automatic Control Sub-Contractor, shall cooperate fully as required.
 4. Ascertain specifically that the calibration, adjustment and settings of the Automatic Control and Monitoring Systems are correct for the proper operation of the systems. Verify sequence of operation.
 5. The TAB Contractor shall submit data on the results of all testing, adjusting and balancing and shall participate in Operating Tests as described elsewhere herein.
- E. *Specifications shall require the following specific procedures by TAB Contractor:*
1. Submittals to the A/E and University:
 - a. Written step-by-step procedures to be used for the testing and balancing of each system at least sixty (60) days, before starting balancing work. Step-by-step procedures shall include specific reference to components and sequence of testing, adjusting, and back checking. Include a complete set of all blank test forms that will be utilized for all testing and balancing reports. Also include estimated start and completion dates for testing and balancing each air and water system.
 - b. List of instruments to be used for each test. Include instrument calibration certificates and dates.
 - c. Ductwork, piping and instrumentation and control shop drawing review report including sign-off of shop drawing acceptance and marked up drawings indicating deficiencies needed to be rectified prior to the start of balancing work. The sign-off of shop drawing review represents that the TAB Contractor has reviewed the shop drawings and either agrees to the completeness of the layouts for balancing purposes or is submitting marked up drawings indicating deficiencies needed to be rectified prior to the start of balancing work.

- d. Duct leakage review reports which include sign-off of acceptance, and comments to the sheet metal contractor(s) duct leakage reports as well as the one (1) witnessed test required for each sheet metal contractor.
 - e. Field inspection reports including marked up drawings indicating deficiencies needed to be rectified prior to the start of balancing work for each applicable system.
 - f. Prior to the start of the final balancing of each system, submit a report that certifies that initial balancing is complete and the previous deficient work identified in the field inspection report has been rectified and that each system is ready for final balancing.
 - g. One (1) set of marked up sheet metal shop drawings which indicate locations of all traverse duct readings, average velocity at each location, average airflow (cfm) at each location and index key to reference the actual traverse duct reading test sheets.
 - h. Bound final testing and balancing reports in agreed quantity which incorporates all final testing and balancing reports including standard AABC or NEBB data sheets, and specialties such as laboratory fume hood system testing and balancing, and verification of direction of airflow if required.
2. *Execution:*
- a. Perform the work, using methods and test forms published by AABC National Standards for Total System Balance, or using equivalent NEBB or Test, Adjusting and Balancing Bureau (TABB) methods and forms.
 - b. Attend project coordination meetings.
 - c. Do not start final testing and balancing until each system has been certified by the Mechanical Contractor(s) to be complete and initially balanced.
 - d. Perform the final testing and balancing of air handling systems with finished ceilings and partitions in place, and doors closed.
 - e. The Owner's Representative and/or Construction Manager may witness initial and/or final testing and balancing of all systems. The Testing and Balancing Agency shall notify the Owner's Representative and Construction Manager five (5) working days prior to each system being tested or balanced.
 - f. Repair or replacement of finished products damaged by personnel employed by the TAB Contractor as a result of testing, balancing and inspection work shall be the responsibility of the TAB Contractor. Repair or replace

- finished products damaged in providing access to areas or in providing support for testing and balancing work.
- g. Perform complete balancing services for standby equipment (if applicable). Verify and report that design air and/or water flows are achieved when operation is switched to standby equipment.
 - h. Provide written certification of the accuracy of all instruments used by the Testing and Balancing Agency. Show date and method of calibration. All instruments shall have been calibrated within six (6) months prior to the estimated commencement date of testing and balancing work.
 - i. Verify the accuracy of all permanently-installed flow-measuring primary elements and their read-out instruments, thermometers, sensors, and pressure gauges furnished by the mechanical installer.
 - j. Review sheet metal, piping, and instrumentation and control Shop Drawings to ensure that the proper balancing devices (dampers, balancing valves, control dampers, control valves, etc.) will be installed into the systems prior to the start of any balancing work. As required, mark up each Shop Drawing to indicate the type and location of balancing device that is required to be installed, so that the systems may be properly balanced. In addition, make note on the Shop Drawings of any deficiencies that need to be rectified prior to the start of balancing work.
 - k. Witness one (1) duct leakage test performed by each sheet metal contractor. Coordinate exact duct leakage tests to be witnessed with the Owner's Representative and Construction Manager prior to witnessing any tests.
 - l. The TAB Contractor shall perform field inspections prior to the installation of the ceiling grids to confirm that the balancing and instrumentation and control devices are installed and operational. The A/E shall specify the frequency of inspections.
 - m. Initiate initial testing and balancing after mechanical contractor's certification of system performance (before controls, ceilings, walls, etc. are completed). Confirm that source devices are operating within 10% of their scheduled values.
 - n. Final balancing shall achieve design air, steam and hydraulic flow rates, within a tolerance of plus or minus 5 percent, at terminal points (air outlets, inlets, transfer air quantities, coil flow rates, etc.). Flow rates at fans and pumps shall be no less than that shown on the Drawings, specified or scheduled. Where the supply and return air fans of air handling units are

- of variable air volume (VAV) operation type, adjust both fans for similar control ranges. Transfer airflow direction shall be in accordance with the drawings in all modes of operation.
- o. All pressure independent ductwork systems (Variable Air Volume Systems) must be balanced at an optimum system static pressure (the minimum required working static pressure). The last air terminal box of each branch duct for each system must be balanced at a minimum of 90 percent of its full open damper position at its scheduled maximum airflow rate. Within the final testing and balancing reports, record the percent opens damper position for each end of branch air terminal box.
 - p. Balance air system in all modes of operation, described in the sequences of operation specification, including as applicable: unoccupied, occupied non-production, occupied in-production, warm-up, economizer and emergency modes.
 - q. Where variable or initial fixed sheaves have been provided, determine the correct fan rpm, and advise the Mechanical Contractor(s) of the correct fan rpm and the required fixed-sheave diameter. Final fixed sheaves shall be sized such that, upon final balancing, the balancing devices at the fan and in the highest pressure drop duct run are open. This means do not “choke” excess fan capacity to achieve final system balance; instead, decrease the fan speed (rpm) as required. Check and verify fan speed (rpm) following installation of fixed sheaves.
 - r. All fan systems with filters shall be balanced to the design cfm with simulated “dirty” filter condition.
 - s. Verify that all controls and final control elements, such as valves, dampers, and air terminal boxes, operate as they are intended and in the sequence specified. Report all device failures in reports submitted.
 - t. Permanently-installed flow-measuring elements may be used to accomplish balancing after accuracy has been verified with certified calibration instruments. Provide document stating equipment used to verify flow. Record and report readouts of these instruments for all flows, even if not required for testing and balancing results.
 - u. Only direct-flow measurement may be used. Do not use indirect calculations, such as a heat balance or pressure drop, unless specifically approved by the Owner’s Representative and Design Professional.
 - v. Provide required openings for duct traverses. Seal test holes in ducts with snap-in plugs. Tape is not permitted. Repair

- insulation where damaged. Mark insulation or exterior of duct where readings were taken.
- w. Perform specific specified balancing procedures for air terminal boxes, humidifiers, laboratory fume hoods, bio-safety cabinets, etc.
 - x. Conduct a contaminant containment test on each fume hood after the fume hood face velocities have been balanced. Fume hood face velocity and contaminant performance shall be tested in accordance with the ASHRAE Standard 110-1995. Refer to Section 15010 for additional requirements.
 - y. Relative differential pressures between spaces in the laboratories and holding rooms and support rooms are critical. Transfer air quantities and directions of flow between rooms are indicated on the Contract Documents for all spaces where relative space pressure differentials are required. As the systems are balanced, determine actual transfer air quantities from supply, return, and exhaust air readings, and include with balancing reports. Adjust supply/exhaust air quantities so that each space achieves the proper relative pressure in the occupied, unoccupied, and other modes of operation. The rate of transfer air into or out of spaces shall be constant between maximum and minimum airflow set points for control of room relative pressure. Provide calibration data on Magnehelic gauges used in these locations. Gauges should have calibration stickers attached to them with calibration date not to exceed one year.
 - z. Record test data where applicable on the following test forms defined in Chapter 26 of AABC National Standards for Total System Balance (or equivalent NEBB forms).
 - 1) Air Moving Equipment Test Sheet: Form No. 82030.
 - 2) Exhaust Fan Data Sheet: Form No. 82031.
 - 3) Fan and Motor Pulley: Form No. 82034.
 - 4) Duct Traverse Readings: Form No. 82035.
 - 5) Duct Traverse Zone Totals: Form No. 82036.
 - 6) Air Distribution Test Sheet: Form No. 82040.
 - 7) Terminal Units: Form No. 82041.
 - 8) Electric Duct Heater: Form No. 82050.
 - 9) Pump Data Sheet: Form No. 82060.
 - 10) Cooling Tower: Form No. 82070.
 - 11) Chillers: Form No. 82080
 - 12) Primary Heat Exchanger: Form No. 82090.
 - 13) Cooling Coil Data: Form No. 82100.
 - 14) Heating Coil Data: Form No. 82101.
 - 15) Sound Level Report: Form No. 82300.
 - 16) Octave Band Chart: Form No. 82301.

- aa. In addition to data required on AABC or NEBB forms, the following additional information is required for all scheduled equipment:
- 1) **Motors:** Type, amps per phase, frame number, model number, serial number, motor horsepower, and calculated driven equipment brake horsepower and efficiency at final conditions.
 - 2) **Fans:** Blade design type such as air foil (AF), backwardly inclined (BI), forward curved (FC), single inlet single width (SISW) or double inlet width (DIDW), class and number of blades.
 - 3) **Pumps:**
 - i. Design Data: Impeller size, motor hp, rpm, net positive suction head (NPSH) required at design flow, and total dynamic head (TDH) at zero flow.
 - ii. Test Data: Suction and discharge pressures at full flow (not throttled to obtain rated flow), and zero flow.
 - 4) **Hydraulic Systems:** Flow rate in each significant branch, and position of each balancing valve. Flow rate to each piece of equipment including each cell of cooling tower.
- bb. **Fan and Pump Systems:** For systems controlled by static pressure, assure by test and recording that devices, including high-limit safety controls are calibrated to perform in accordance with Contract Documents, and the system provides design static pressure at most demanding location. Furnish and coordinate static pressure set point of controls, as applicable, with the installation of Automatic Control Systems.
- cc. **HEPA Filter Testing:** Perform particulate challenge field testing and certification of all HEPA filters installed under this project to demonstrate that filter installation meets specified efficiency. Exhaust HEPA filters shall be tested in accordance with Mil-Std 282, Federal Standard 209E and filter/filter housing manufacturer's written recommendations following testing and balancing certification, and just prior to Owner's acceptance. Supply HEPA filters shall be tested in accordance with IES-RP-CC001.3, Federal Standard 209E and filter/filter housing manufacturer's written

recommendations following testing and balancing certification and just prior to Owner's acceptance.

dd. In locations specified, conduct sound tests in accordance with procedures published by AABC or NEBB, except as modified by the following:

- 1) At each designated location, measure sound pressure level at each octave band mid-frequency between 63 and 8000 Hz.
- 2) Based on these sound pressure level measurements, calculate and report "RC" rating and sound level (DBA) for each designated location. Plot center frequencies for each octave band on RC curve charts.

ee. **Automatic Control and Monitoring Systems:**

- 1) Check the correct installation and proper operation of complete Automatic Control Systems in accordance with the approved Shop Drawings and specified design criteria.
- 2) Verify calibration, adjustments and settings of all controls and proper operation of all valves and dampers.
- 3) Supervise all adjustment procedures and corrective actions taken by Automatic Control Contractor and identify all changes affecting the Testing and Balancing scope of work.

END OF SECTION