

SECTION 15990 - TESTING, ADJUSTING AND BALANCING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK:

- A. This section covers testing and balancing of environmental systems described herein and specified under Division 15. The testing and balancing of all environmental systems shall be the responsibility of one Testing, Balancing and Adjusting firm.

EDIT NOTE: This section contains many specialized systems, which are job specific. Edit out all systems, which are not applicable.

1. Test, adjust and balance the following mechanical systems and the mechanical equipment associated with these systems:
 - a. General Systems and Equipment Procedures.
 - b. Air Side Systems and Equipment
 - 1) Supply/Return Air Systems
 - 2) General Exhaust/Supply Fans
 - 3) Air Handling Units
 - 4) General Exhaust Systems
 - 5) Cabinet/Unit Heaters
 - 6) Unit Ventilators, Furnaces, Packaged Air Conditioning Units
 - 7) Lab and Research Facility Systems Kitchen/Service Hood Exhaust Systems
 - c. Hydronic Systems and Equipment
 - 1) Heating/Chilled water systems
 - 2) Condenser water systems
 - 3) Hydronic coils
 - 4) Radiators/Convectors
 - 5) Heat exchangers
 - 6) Hydronic Pumps
 - 7) Heating Water Boilers
 - d. Plumbing
 - 1) General
 - 2) Sewage Ejector/Sump Pumps
 - 3) Booster pumps
 - 4) Water heaters
 - 5) Pure Water Distribution Systems
 - 6) Fuel Oil Systems
 - 7) House Compressed Air
 - e. Steam Systems and Equipment
 - 1) General
 - 2) Steam coils
 - 3) Boilers
 - 4) Humidification systems and equipment

- f. Refrigeration Systems and Equipment
 - 1) General
 - 2) Chillers
 - 3) Cooling Towers
 - 4) Condensing units
 - 5) Evaporator coils
- g. Gas Fired Systems and Equipment
 - 1) General
- h. Electrical Components
 - 1) Electric resistance heating
 - 2) Manual and magnetic starters
 - 3) Variable frequency drives
- i. Control Systems and Equipment
 - 1) General
 - 2) TC compressed air
- j. Life Safety Systems and Equipment
 - 1) Smoke pressurization, exhaust, and evacuation modes
 - 2) Fire/smoke dampers and detection systems
 - 3) Engine generator systems and equipment

1.2 QUALIFICATIONS OF CONTRACTOR:

- A. The Mechanical Contractor shall procure the services of an independent testing and balancing agency specializing in the testing, adjusting and balancing of environmental systems to perform the above mentioned work. An independent contractor is defined as an organization that is not engaged in engineering design or is not a division of a mechanical contractor entity, which installs mechanical systems.
- B. The actual fieldwork shall be performed by qualified technicians who are currently certified by the Testing, Adjusting and Balancing Bureau (TABB), the National Environmental Balancing Bureau (NEBB), or the Associated Air Balance Council (AABC) certification agencies.
- C. The Testing & Balancing Contractor shall have a minimum of three years experience in testing and balancing mechanical systems.

NOTE: MAKE SELECTION AS REQUIRED BY JOB CONDITIONS. ***Paragraph "E" cannot be accomplished by most firms.

- D. The Test & Balance Contractor shall have previous experience in testing and balancing variable air volume laboratory fume hood systems in the last two years. Qualification submission must include a detailed resume describing past project experience in laboratory variable air volume systems, a list of projects, including peoples' names, phone numbers and addresses of references.
- E. Testing and balancing work shall be directly supervised by a Registered Engineer and the results attested to by a Registered Professional Engineer on the Testing & Balancing

Contractor's staff. The Engineer shall represent the Testing & Balancing Contractor in progress meetings as requested, and shall be available for interpreting all material found in the balance report.

1.3 APPROVAL OF CONTRACTOR:

NOTE: MAKE SELECTION AS REQUIRED BY JOB CONDITIONS.

A. Following are firms acceptable to do the work:

DESIGN NOTE: CONFIRM LIST WITH OWNER, REVIEW FOR PROJECT LOCATION, DISCUSS APPROVED LIST WITH PRINCIPLE.

1. JEDI Balancing
1414 Washburn Street
Erie, CO 80516
(720) 839-5333
2. Air Right Inc.
3. Lawrence H. Finn & Assoc.
4. Griffith Engineering Service
5. JPG Engineering
6. Rocky Mountain Balancing Co.
7. TAB Services, Inc.
8. Complete Mechanical Balancing
9. Double T Balancing Company
10. Controlled Air, Inc.
11. Midwest Engineering
12. Checkpoint Balance
- 13.

OR

B. Any Testing and Balancing firm desiring to offer their services for this work shall submit their qualifications to the [Architect/Engineer], not less than [seven (7) _____] working days before the bid date. Approval or disapproval will be given on each request and this action will be given in writing prior to bidding the work.

1.4 CODES AND STANDARDS:

- A. ASHRAE: ASHRAE Handbook, Systems Volume, Testing, Adjusting, and Balancing.
- B. NEBB: "Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems."
- C. SMACNA: "HVAC Systems-Testing, Adjusting & Balancing."

1.5 PRELIMINARY SUBMITTALS:

- A. Within ten (10) days of award of the contract the Mechanical Contractor shall submit the name of the Test and Balance Contractor who will be performing the work. The submittal shall include a complete list of all technicians who will be performing the field work and include a photocopy of their current certification by either NEBB, AABC, or TABB certification agencies. Only those technicians included in the submittal shall perform the work. Any personnel or staff used to perform the work without prior approval of the Engineer, who are not included in the submittal, shall be grounds for rejecting the test and balance report and the project in whole.

- B. Meet all requirements of Section 15010 as applicable.
- C. Submit a list of all instrumentation to be used on an individual project and include calibration dates. Submit calibration curves. If more than one instrument of a similar type is used, a comparison of individual readings should be made. The variation between instrument readings should not exceed plus or minus 5%.

EDIT NOTE: Delete following paragraph if a Preliminary Systematic Procedure is not included under Section 3.1.

- D. Prior to the start of any test and balance work of the mechanical system, the Contractor shall submit six (6) copies of a Preliminary Systematic Procedure. This shall include all preliminary information requested in Part 3 of this Section.

1.6 FINAL REPORTS:

- A. Refer to Division 1 for supplemental requirements.
- B. The Testing and Balancing Contractor shall submit six (6) bound copies of the final testing and balancing report at least fifteen (15) calendar days prior to substantial completion, unless noted otherwise in Division 1. Report contents shall be per Part 3 of this Section.
- C. Meet all requirements of Section 15010 as applicable.
- D. If more than two reports are made by the contractor, the Owner reserves the right to charge the contractor for subsequent reviews by their consultants. Such extra fees shall be deducted from payments by the Owner to the contractor.

1.7 SEQUENCING AND SCHEDULING:

- A. Notify Contractor/Engineer/Architect in writing of conditions detrimental to the proper completion of the test and balance work. Provide the Contractor/Architect/Engineer with a copy of the notification.
- B. Prepare a project schedule. Schedule shall indicate critical path of the balancing process and shall incorporate both requirements of other contractors necessary to meet test and balance commitments and process flow of test and balance work. Coordinate with general and mechanical contractors and insert critical steps into project master schedule.

PART 2 - PRODUCTS

2.1 BELTS, SHEEVES, IMPELLERS:

- A. Refer to specific equipment sections and Section 15010 for additional requirements.
- B. The Testing & Balancing Contractor shall coordinate with the Mechanical Contractor to supply correctly sized drive belts and sheeves. Impellers shall be trimmed or replaced by the mechanical contractor and shall be correctly re-sized and coordinated by the Test and Balancing Contractor per the hydronic systems and equipment portion of this section.

EDIT NOTE: PARAGRAPH SHALL REMAIN FOR VFD SYSTEMS

- C. The Test & Balance Contractor shall determine the fan belt and sheeve replacement necessary for final balance condition for specified air quantity when the VFD is operating in the by-pass mode for final field conditions, without placing the motor over its nameplate amp rating.

PART 3 - EXECUTION

3.1 PRELIMINARY PROCEDURES:

- A. Testing and balancing shall not begin until the system has been completed and is in full working order and the following project conditions have been determined suitable for start of work.
1. Preliminary Testing & Balancing Contractor requirements shall be ascertained prior to the commencement of work through a review of the project plans and specifications. In addition, visual observations at the site during construction shall be made to determine the location of required balancing devices, that they are being installed properly, and in an accessible location for the need. Report in writing any deficiencies to the Contractor/Engineer/Architect immediately.
 2. Before any air balance work is done, the system shall be checked for duct leakage (obtain pressure test results), assure filters are installed, verify filters are changed if they are dirty, check for correct fan rotation, equipment vibration, and check automatic dampers for proper operation. All volume control dampers and outlets shall be wide open at this time.
 3. Before any Hydronic, domestic water or applicable system balancing work is done, the systems shall be checked for plugged strainers, proper pump rotation, proper control valve installation and operation, air locks, proper system static pressure to assure a full system, proper flow meter and check valve installation. All throttling devices and control valves shall be open at this time.
 4. Verify systems do not exhibit excessive sound and/or vibration levels. Report in writing any deficiencies to the Contractor/Engineer/Architect immediately.

EDIT NOTE: Having the T&B contractor prepare and CRA reviewing a preliminary systematic procedure will add cost and engineering time to a project. Delete items B&C except for very large or critical operation jobs. Present this to Owner and obtain approval prior to specifying this section.

3.2 PRELIMINARY PROCEDURES – REMODEL WORK:

- A. In remodel area, a complete preliminary test and balance report shall be accomplished prior to any work. Any obvious deficiencies shall be identified at that time. A complete report of all readings, recommendations, etc. shall be submitted to the Engineer.

3.3 GENERAL SYSTEM AND EQUIPMENT PROCEDURES:

- A. Balance all air and water flows at terminals within +10% to -5% of design flow quantities. Notify Contractor/Engineer/Architect in writing of conditions detrimental to the proper completion of the test and balance work. Provide the Contractor/Architect/Engineer with a copy of the notification.
- B. Pressure relationships indicated on drawings shall take priority over air quantities.

- C. Mark equipment settings with paint, including damper control positions, balancing cocks, circuit setters, valve indicators, fan speed control settings and similar controls and devices, to show final settings at completion of test-adjust-balance work.
- D. Patch holes in insulation, ductwork and housings, which have been cut or drilled for test purposes, in a manner recommend by the original installer.

DESIGN NOTE: Confirm balance criteria with Owner's published standards, +10%/-5% Is CRA standard.

- E. Measure, adjust and report equipment running motor amps and power factor, KW, rated motor amperage, listed motor power factor, voltage, and all nameplate data. Perform these measurements for all equipment operational modes.
 - F. Check and adjust equipment belt tensioning.
 - G. Check keyway and setscrew tightness. Report any loose screws and notify Mechanical Contractor prior to equipment balancing.
 - H. Record and include in report all equipment nameplate data.
 - I. Verify that all equipment safety and operating controls are in place, tested, adjusted and set prior to balancing.
 - J. Verify that manufacturer start-up has occurred per specification prior to balancing.
- 3.4 AIR SIDE SYSTEMS AND EQUIPMENT PROCEDURES:

EDIT NOTE: This section contains many specialized systems which are job specific. Edit out all systems, which are not applicable.

- A. In addition to the procedures identified under each specific heading below, provide general data required by 3.2 above.
- B. Filters shall be restricted to increase pressure drop to 50% of span between initial pressure drop and final recommended pressure drop for setting final airflows for fans. Check fan motor amps with clean filters and simulated loaded filters, and report for each piece of equipment. Equipment shall be supplied with clean filters upon completion of balance. Balance and report air quantities.
- C. Supply/Return Air Systems:
 1. Balance and report supply and return diffuser/grille quantities. Air diffusion patterns shall be set as noted on drawings and to minimize objectionable drafts and noise.
 2. Provide full pitot traverses in duct mains downstream of supply fans, upstream of return fans, and in each zone duct downstream of a multizone unit. For VAV systems perform these at the system diversity condition (if any). Balance and report air quantities.
 3. Provide full pitot traverses at each air terminal or duct coil. For VAV systems, perform these at zone maximum air condition. Balance and report air quantities.
 4. Report design air device inlet or outlet size, actual inlet or outlet size, design and actual velocity through the orifice, for each terminal in the system.

5. Balance and report the above measurements in all system operational/modes.
 - a. Minimum outside air and 100% outside air economizer mode.
 - b. VAV maximum zone air condition and system diversity condition.
 - c. Unoccupied mode.
 - d. Two-speed fan, both speeds.
 - e. VFD bypass mode and full system demand.
 - f. General Exhaust/Supply Fans:
- D. Adjust CFM to system requirements. For belt drive include sheave and belt exchange to deliver airflow within limits of installed motor horsepower and mechanical stress limits of the fan. Determine the limiting fan tip speed before increasing RPM. Final fan speed setting shall allow for filter loading (as applicable) and shall establish proper duct pressures for operation of zone CFM regulators. For direct drive with speed taps: Set fan speed on tap which most closely approaches design CFM by adjusting the speed control After adjustment, check fans ability to re-start after powering down. Increase setting if required for proper starting.
 1. Measure and report static pressures upstream and downstream of all fans.
 2. Measure and report fan RPM.
 3. Report design fan inlet or outlet size, actual inlet or outlet size, design and actual velocity through the orifice.
- E. Air Handling Units:
 1. On outdoor units, verify that positively or negatively pressurized curbs are free of leaks. Report.
 2. For units with integral outside air intake and relief dampers, measure, adjust, set and report outside air, return air and relief air quantities. Perform this as specified under supply air systems.
 3. Balance and report supply and return fan CFM, upstream static pressure and downstream static pressure.
 4. Measure and report static pressure upstream and downstream of all AHU components such as coils, filters (clean and simulated dirty), dampers, etc.
 5. After system and fan balance is complete, perform pitot traverses on all coils in 100% heating and cooling modes.
 6. Units with economizers shall have all measurements performed and reported at minimum outside air, 100% outside air, and a 50/50% mixed air condition.
 7. Units with operation modes for smoke evacuation and/or pressurization shall have all measurements performed and reported for all modes.
 8. Balance variable air volume AHU fans for system design diversity. Supply and return fan static pressures shall be optimized for VAV system terminal device pressure

requirements. Report fan, motor and VFD information as previously indicated. Verify that an overload condition does not exist when all system VAV boxes are 100% open.

9. Balance all air handling unit coils and report per hydronic, gas fired, steam or refrigeration equipment portions of this section.
10. Report design fan inlet or outlet size, actual inlet or outlet size, design and actual velocity through the orifice.
11. Balance and report all temperatures of airside and hydronics during normal operating modes.
12. Measure, adjust, set, balance and report outside air, return air and exhaust/relief air quantities for all air handling systems.

Air quantities shall be determined by pitot traverse/direct airflow measuring procedures where ever possible, where duct/inlet conditions do not allow for accurate direct measurement of outside air the following method shall be used:

$$\text{Outside Air CFM} = \frac{\text{Supply Fan Total CFM}}{\text{Return Fan Total CFM}}$$

In addition to the direct measuring of airflow quantities, measure and record outside air, return air and mixed air temperatures, determine thermal/mass energy balance and provide calculations to verify measured airflow quantities. Adjusting and setting the outside air quantity as a percentage of damper position will not be acceptable.

F. General Exhaust Systems:

1. Balance and report exhaust grille quantities. Report objectionable noise.
2. Provide full pitot traverses at each individual exhaust riser and at each exhaust fan. Balance and report.
3. Report design air device inlet or outlet size, actual inlet or outlet size, design and actual velocity through the orifice, for each terminal in the system.

G. Cabinet/Unit Heaters:

1. Balance and report entering and leaving air temperature. Report airflow.
2. Balance all coils per hydronic, gas fired or steam equipment portions of this section.

H. Unit Ventilators/Furnaces/Packaged Air Conditioning Units:

1. Report static pressure across all unit components.
2. Balance and report supply air, return air and outside air quantities.
3. Report mixed air temperature and balance coils per hydronic, steam, electric resistance, gas fired or refrigeration portions of this section.

I. Laboratory and Research Facility System Requirements:

1. General requirements:

- a. Balance all rooms to required pressure relationships as noted on the drawings. Document in the test and balance report that all pressure relationships have been set as specified.
 - b. Performance testing of the Room Pressurization Control System and the fume Hood Exhaust System shall be performed after the entire mechanical system for the building is complete. All systems shall have been calibrated, tested and balanced before performance testing begins.
 - c. Performance testing shall be done by the balancing contractor in the presence of the Owner, user groups, and a representative from the Department of Environmental Health and Safety.
 - d. The performance testing must be successfully completed before the Owner will accept control of the building's mechanical system.
2. Fume Hood Exhaust Systems:
- a. Measure and set flows for all fume hoods, flammable storage cabinets, etc.
 - b. Perform full Pitot traverses upstream of exhaust fans and balance and report air quantities. Perform this in fully open and closed hood sash positions.
3. Fume Hood Exhaust System Performance Evaluation:
- a. The Balancing Contractor shall demonstrate that the exhaust system and pressure relationships are performing properly under the conditions listed below.
 - b. Verify that the exhaust fans on the roof are operating properly. The discharge dampers should be performing as specified and the fans should be operating smoothly without surging or vibrating excessively.
 - c. During each step in the testing procedure, note any rooms, which exhibit excessive noise.
 - d. Testing Conditions:
 - 1) With all fume hood sashes closed:
 - a) Check the relative pressure relationships with smoke in several rooms on each floor.
 - 2) With all fume hood sashes open:
 - a) Check the face velocity of the hood closest to and farthest from each exhaust riser. Do this on every floor.
 - 3) Close all the fume hood sashes served by one exhaust riser and open all the ones served by the other riser.
 - a) Check the hoods with open sashes as for a.1) above
 - 4) Repeat condition b. for the second riser.
 - 5) Move all the fume hood sashes to a half open position.

- a) Check the hoods as above.
 - 6) Final balance shall be based upon diversity provided by the Engineer. Note diversity on balance reports. The hood face velocities, relative pressure relationships and stable fan operation must be recorded for all five-test conditions. This applies to all hoods and all rooms in the wing being tested, even if the test procedure does not specifically state that particular hood or room be tested. Design conditions with the appropriate diversity shall be maintained.
 - 7) The face velocity of a hood shall be considered acceptable if it is within (+) 10 feet per minute of its designed face velocity. Standard procedures for testing face velocity as published by SEFA (Scientific Equipment & Furniture Association) 1-1992 Laboratory Fume Hoods Recommended Practices, shall be followed.
4. Room Pressurization Control System Performance Evaluation:

The Balancing Contractor shall demonstrate with smoke that the correct relative pressure relationship is being maintained in each area. Every room for which a relative pressure value was assigned on the mechanical plans shall be tested.

The testing shall be performed in each room under the following conditions:

- 1) Door closed
 - 2) Door open
 - 3) In labs with fume hoods or bio-safety cabinets:
 - a) Hood sash complete open
 - b) Hood sash closed
 - c) Hood sash partially open
 - 4) Thermostat set to its minimum set point
 - 5) Thermostat set to its maximum set point
 - 6) If the correct pressure relationships cannot be demonstrated for a particular room, the room shall be retested after the problem has been corrected.
- J. Kitchen/Service Hood Exhaust Systems:
- 1. General Requirements:
 - a. Balance all rooms to required pressure relationships as noted on the drawings. Document in the test and balance report that all pressure relationships have been set as specified.
 - b. Performance testing of the Room Pressurization Control System and the Hood Exhaust System shall be performed after the entire mechanical system for the building is complete. All systems shall have been calibrated, tested and balanced before performance testing begins.
 - c. Set, measure and report flows for all hoods.
 - d. Perform full pitot tube traverses upstream of exhaust fans and balance and report air quantities.

- 1) In welded high temperature systems provide air quantities upstream of exhaust fans by summing the flows at all hoods.
- e. Measure and report hood capture velocity profiles.
2. Exhaust system performance evaluation.
 - a. Verify room pressure relationships with smoke tests and report. The testing shall be performed in each room under the following conditions:
 - 1) Door closed
 - 2) Door open
 - 3) Thermostat set to its minimum set point
 - 4) Thermostat set to its maximum set point
 - 5) If the correct pressure relationships cannot be demonstrated, the room shall be retested after the problem has been corrected.
 - b. Verify hood capture velocities are adequate with smoke tests and report.
 - c. Verify that the exhaust fans on the roof are operating properly. The fans shall be operating smoothly without surging or vibrating excessively.

3.5 HYDRONIC SYSTEMS AND EQUIPMENT:

A. Heating/chilled water systems:

1. **Hydronic Systems With Meters:** The system shall be balanced proportionally using the flow meters. On completion of the balance, the following information shall be recorded in the report: Flow meter size and brand, required flow rate and pressure drop, valve settings on meters with a readable scale, flow rate in both full coil flow and full bypass modes. Contractor shall verify the meters are installed per the manufacturer's recommendations and shall notify the Mechanical Contractor of any deficiencies before utilizing meter.
2. **Hydronic Systems Without Meters (thermal or terminal rated pressure drop balance):** The system shall be balanced proportionally to the terminal ratings. On completion of the balance the following information shall be recorded in the report: Design entering and leaving water temperature/pressure, final balanced entering and leaving water temperature/pressure drop.
3. For 3-way valve terminals/heat exchangers, set bypass flow to equal coil flow.
4. For primary/secondary systems, set crossover/bride to have constant flow at all conditions.
5. Sample chilled and heating water and report on freeze and burst temperatures of the glycol water solution. Report glycol percentage.
6. Perform similar operations for Hydronic heat reclaim systems.

B. Condenser Water Systems and Equipment:

1. Measure and record system static pressure with pumps off.
2. Where 3-way bypass is used to control condenser water temperature set the control valve pressure valve to equal tower pressure drop in full bypass mode.

3. Measure, set and record system gpm at all flow measurement stations.
- C. Hydronic Coils:
1. Balance, measure and report inlet and outlet air temperatures for cooling and/or heating design air quantities.
 2. Balance, measure and report coil water flow, inlet and outlet water pressure and temperature.
 3. Evaporative cooling coils: Measure and report inlet and outlet wet bulb and dry bulb temperature. Measure and report inlet and outlet pressure.
 4. Calculate and report face velocities across chilled water and evaporative cooling coils.
- D. Radiators and Convectors:
1. Balance, measure and report GPM, inlet temperature and outlet temperature/pressure at full heating.
- E. Heat Exchangers:
1. Balance, measure and report water flow for full heating.
 2. Report inlet and outlet water pressures and temperatures for full heating.
 3. For steam to water heat exchangers, see steam equipment portion of this Section for additional requirements.
- F. Hydronic Pumps:
1. Adjust and balance pumps to provide design system flow rate, and design flow to most remote system location. Trim or replace impellers as necessary to achieve this. Do not induce false head to achieve balance results, without the prior approval of the Engineer. See Part 2 - "Products" of this section.
 - a. Prior to trimming of impellers, notify the Architect/Contractor/Engineer in writing of performance of pumps with and without false head induced.
 2. Report impeller size, flow rate, inlet and outlet water pressure and pump shut-off head. Provide pump curve and operating point in final report. Include compensations for temperature and percentage glycol.
- G. Heating Water Boilers:
1. Verify that the boiler has been properly cleaned, flushed and the burner is operating properly prior to balancing.
 2. Check and report on proper operation of boiler feed pumps.
 3. Confirm automatic and manual air vents are working properly. Vent system as necessary.
 4. Balance, measure and report boiler water flow rate, inlet and outlet temperature and pressure.

5. Confirm that temperature and pressure safety relief valves are located properly and in working order.
6. Verify proper operation of emergency power OFF switches.

3.6 PLUMBING SYSTEMS AND EQUIPMENT:

A. General:

1. Check, adjust and set temperature control devices to [110 F] domestic hot water temperature and as indicated on drawings.
2. Adjust pressure-reducing stations, report downstream system static pressure.
3. Verify proper location and operation of ASME pressure and temperature relief valves.
4. Measure and report residual pressure at full flow at most remote plumbing fixture; requiring highest operating pressure (usually flush valve water closets).
5. Verify that most remote fixture has hot water available semi-instantaneously with recirculation system operating. Report.

B. Sewage Ejector/Sump Pumps:

1. Verify proper discharge of sewage ejector and sump pump systems. Verify that units are meeting system demands. Report.

C. Booster Pumps:

- a. Measure and report inlet and outlet pressure and flow rate.
- b. Balance pumps per Hydronic portion of this Section.

D. Water Heaters:

- a. Measure, set and report inlet and outlet temperatures.
- b. Balance and report per steam, electric or gas portions of this Section.

E. Pure Water Distribution Systems:

1. Verify and report flow at all stations.
2. Verify and report operation of irradiation devices.
3. Measure and report recirculation system flow rate.
4. Remove, inspect and clean all system particulate filters and strainers.

F. Fuel Oil Systems and Equipment:

1. Remove, inspect and clean all system filters/strainers.
2. Verify correct operation of fuel oil tank level gauges. Report

3. Verify and report operation of all pumps, feed pumps and transfer pumping systems. Verify that they are meeting system requirements.

G. House Compressed Air Systems and Equipment:

1. Verify and Report air pressure at all system equipment quick connects and terminations.
2. Remove, inspect and clean all system filters/strainers.
3. Verify system can maintain overrating pressure for 8 hours with air compressor disconnected. Report any noticeable losses in system pressure.
4. Measure, set and report storage tank air pressure.
5. Verify that pressure relief valves are in place and operating correctly.

3.7 STEAM SYSTEMS AND EQUIPMENT:

A. General:

1. Check steam traps for correct operation with a pyrometer.
2. Check and report all steam pressures downstream of pressure reducing stations.
3. Remove, inspect and clean all system strainers.
4. Record steam pressures upstream and downstream of all major equipment such as boilers, steam coils and heat exchangers.

B. Steam Coils.

1. Measure and report entering and leaving air temperatures at full heating.

C. Boilers:

1. Verify that the boiler has been properly cleaned, flushed and the burner is operating properly prior to balancing.
2. Check and report on proper operation of boiler feed pumps.
3. Verify boiler water level is proper and steady during operation.
4. Confirm that temperature and pressure safety relief valves are located properly in working order.
5. Verify proper operation of emergency power OFF switches.

D. Humidification Systems and Equipment:

1. Measure and report steady state relative humidity for spaces.
2. Measure and report humidifier outlet relative humidities.
3. Steam Dispersion Grids:

- a. Measure and report entering and leaving air temperature, and leaving relative humidity.
 - b. See steam portion of the Section.
 - 4. Electric Steam Generators:
 - a. Measure and report operating amps.
- 3.8 REFRIGERATION SYSTEMS AND EQUIPMENT:
- A. General.
 - B. Condensing Units (Air Cooled):
 - 1. Measure and report ambient temperature, refrigerant suction and discharge pressure, oil pressure, compressor and fan KW and compressor and fan amps.
 - 2. Condensing units integral to the air moving equipment shall be measured at minimum outside air.
 - 3. Perform all measurements at all stages of cooling.
 - C. Chillers:
 - 1. Measure, balance and report inlet and outlet chilled water temperature and pressure, ambient temperature, water flow rate, oil pressure, refrigerant suction and discharge pressure, compressor/fan KW and compressor/fan amps.
 - 2. Verify proper operation of emergency power OFF switches and refrigerant sensors.
 - 3. Perform all measurements at all stages of cooling.
 - 4. Coordinate balance process with equipment manufacturer start-up representative.
 - D. Cooling Towers:
 - 1. Measure and report tower entering and leaving air wet bulb temperature. Compare entering wet bulb against ambient wet bulb to verify recirculation is not taking place. Report.
 - 2. Measure and report entering and leaving water temperatures. Report ambient wet bulb that corresponds with these measurements.
 - 3. Measure, balance and report water flow rate.
 - E. Evaporator Coils:
 - 1. Measure and report temperature upstream and downstream of evaporator coils at all stages of cooling at all design air quantities. Calculate and report coil face velocities.
- 3.9 GAS FIRED SYSTEMS AND EQUIPMENT:
- A. General.

1. Record gas pressures downstream of each pressure-reducing valve. Verify that pressures match those on construction documents and report.
 2. Measure and report flue temperature at all stages of heating.
 3. Measure and report temperatures upstream and downstream of gas-fired coils at all stages of heating at all design air quantities.
 4. Observe and report operation of all radiant gas fired heaters, at all stages of heating.
 5. Record fan data.
- 3.10 ELECTRICAL COMPONENTS ASSOCIATED WITH MECHANICAL SYSTEMS:
- A. Electric Resistance Heating Systems and Equipment:
1. Measure full load amperage at full heating and design CFM and report.
 2. Electric heaters in an airstreams shall have entering and leaving air temperature measured and reported for all stages of heating.
- B. Manual and Magnetic Starters:
1. Check all new and existing thermal overloads. Identify improperly protected equipment in report. Furnish and exchange thermals as required for proper motor protection.
 2. Motor Control Center Magnetic Starters: Check for correct sizing. Notify Electrical Contractor of discrepancies.
 3. Two-speed Starters: In addition to the above, set time delay between changes of speeds for proper operation.
 - a. Verify windings of motor and starter are compatible prior to starting any equipment.
- C. Variable frequency drives.
1. Coordinate balance process with equipment manufacturer start-up representative.
 2. Record nameplate data.
 3. Record motor overload setting.
 4. Record full load amps.
- 3.11 CONTROL SYSTEMS AND EQUIPMENT:
- A. General.
1. Operate all temperature control systems with the temperature control contractor's representative for proper sequence of operation. Be responsible for calibration of flow measurement devices used as input to the temperature control system. All air system flow measurement stations including VAV terminals shall be calibrated against a Pitot tube traverse or air diffuser capture hood. Balancing Contractor shall assure accuracy of all flow measurement devices or shall report their failure to be accurate.

2. Work with the Controls Contractor to set minimum outside air damper positions.
3. Work with the Controls Contractor to optimize VAV duct static pressure, VFD pump hydronic system pressure differential and building pressure.

B. Temperature Control Compressed Air Systems and Equipment:

1. Verify and report air pressure at all system equipment quick connects and terminations.
Remove, inspect and clean all system filters/strainers.
2. Verify system can maintain overrating pressure for 8 hours with air compressor disconnected. Report any noticeable losses in system pressure.
3. Measure, set and report storage tank air pressure.
4. Verify that pressure relief valves are in place and operating correctly.

3.12 LIFE SAFETY SYSTEMS AND EQUIPMENT:

A. Smoke Pressurization/Exhaust/Evacuation Mode:

1. Balance and report measurements of Section 3.3 in this operational mode.
2. Perform smoke pressurization/evacuation tests in all zones. Doors shall be positioned to simulate normal conditions.
3. Coordinate with the Fire Department/Authority Having Jurisdiction, Owner and Engineer for smoke test witnessing.
4. Coordinate with the Fire Department/Authority Having Jurisdiction for additional testing requirements. Complete and submit any documentation for Fire Department/Authority Having Jurisdiction final acceptance.

B. Fire/Smoke Dampers and Detection Systems:

1. Verify that each fire/smoke damper closes when the associated duct or space detector is tripped. Verify that air handlers shut down and outside air dampers close as dictated by the control sequence.
2. Verify that air supply units shut down when smoke is detected by the associated duct detector. Verify that outside air dampers and system fire/smoke dampers close as dictated by the control sequence.
3. Report any detectors or dampers that are malfunctioning. Report any discrepancies from the control sequence.

C. Engine Generator Systems and Equipment:

1. For remote radiators, measure and report steady state radiator system flow rate, supply water temperature and return water temperature.
2. Measure and report generator room steady state temperature with generator and room ventilation system running. Report outside air temperature at time of test.

Record pressure relationship of generator room to adjacent spaces and outside.

3. Verify correct sequence of operation of all intake and discharge dampers, supply/exhaust fans, etc.

3.13 SOUND AND VIBRATION:

A. Sound Inspection and Testing:

DESIGN NOTE: Delete items 5, 6, and 7 for jobs without sound level measurement in the contract or without sound level critical spaces. Items 6 and 7 are very expensive.

1. Prior to sound testing, all equipment that can potentially impact sound testing shall be put into operation. Examples include fan coil units, humidifiers, air handling units, and equipment in adjacent mechanical spaces. VFD systems shall be placed at 80% of full speed.
2. Prior to sound testing the mechanical test and balance of all systems shall be completed.
3. Report audible tonal characteristics such as whine, whistle, hum or rumble. Also report time varying sound levels or beats induced from aerodynamic instability, perform this for all rooms.
4. Perform sound testing on all rooms/the following rooms within the project area.
5. Measure cooling tower sound output (DBA). Perform this at full speed for VFD units.

DESIGN NOTE: Consult ASHRAE and Owner Standards for recommended RC level for different types of rooms.

6. Measure and report room sound pressures at the 16, 31.5, 63, 125, 250, 500 1000, 2000, 4000, and 8000 Hz octave bands. Measure and report corresponding RC level. Testing shall be performed after full furnishing of the space. Perform measurements in accordance with procedures outlined in Chapter 34 and 43, ASHRAE HVAC Applications, 1995 Edition.

DESIGN NOTE: Consult Owner and Authority Having Jurisdiction for maximum noise levels at property line. Verify means of measurement (DBA, NC, etc.).

7. Measure and report noise levels (DBA) at the following locations:
 - a. At the property line closest to intake and discharge louvers.
 - b. At the property line closest to rooftop and at grade equipment such as cooling towers and chillers.
 - c. On the roof of adjacent buildings overlooking rooftop equipment within the project area.

B. Vibration Inspection and Testing:

DESIGN NOTE: Delete items 4, 5, 6, 7, 8, 9, and 10 for non-critical jobs. Consider editing spec. to perform these tests only on field assembled components or critical system components. Items 6 thru 10 are very expensive.

1. Prior to vibration testing, all equipment shall be put into operation. On variable speed equipment, testing shall occur at low, medium and high speeds.
2. Prior to vibration testing, the mechanical test and balance of all systems shall be completed.
3. Report excessive vibrations from any equipment. Inspect upstream and downstream duct and piping systems and report excessive vibrations.
4. Verify that all spring and elastomeric isolation systems are installed "free-floating" and are not short circuited to structure by obstructions.
5. Perform a stethoscope check on all accessible bearings. Report excessive vibration or noise.

DESIGN NOTE: Consult ASHRAE for recommended minimum spring isolator efficiencies. Efficiencies to be calculated from information submitted per No.6.

6. Obtain undeflected isolator spring lengths from shop drawings for each piece of equipment, report. Measure and report distance of spring isolator deflection for each of equipment. Measure and report disturbing frequency (Hz) for each piece of equipment.
7. Measure and report motor running speed and driven equipment running speed for each component.

DESIGN NOTE: Consult ASHRAE Applications, Chapter 43, for recommended maximum RMS velocity levels and vibration criteria.

8. Measure and report horizontal, vertical and axial RMS velocity (in./sec.) at equipment structure or bearings.
9. Measure and report horizontal, vertical and axial frequency (Hz.) at equipment structure or bearings.

DESIGN NOTE: The following paragraph should only be kept for vibration analysis of critical laboratory and hospital surfaces. Examples: operating rooms, microscope benches, electron microscope rooms, etc.

10. Measure and report RMS velocity (in./sec.) and frequency for the following surfaces in all three axis's:
11. DESIGN NOTE: See Table 40, Chapter 43, ASHRAE Applications, (1995) for list of surfaces.

3.14 REPORT OF WORK:

EDIT NOTE: Delete all references to Preliminary Systematic Procedure, unless the requirements for this report were left in Section 3.1.

- A. The Testing and Balancing Contractor shall submit six (6) bound copies of the final testing and balancing report at least fifteen (15) calendar days prior to the Mechanical Contractor's request for final inspection.

- B. A complete reduced set of mechanical contract drawings (showing each system) shall be included in the report with all equipment, flow measuring devices, terminals (outlets, inlets, coils, fan coil units, schedules, etc.) clearly marked and all equipment designated. The test and balance contractor can obtain drawing files from Cator, Ruma, & Associates for development of these drawings. These drawings shall be developed from the system schematic drawings submitted in Preliminary Systematic Procedures.
- C. Data shall be reported per Part 3 of this Section on standard NEBB forms. Generate custom forms that contain the information in this Section when a standard NEBB form does not exist for a piece of equipment. All NEBB forms shall be fully filled out for this report. When additional information is required by this Section, it shall be provided. Report forms with design columns filled out shall be used from the Preliminary Systematic Procedure report submitted previously.
- D. The report shall include a list of all equipment used in the testing and balancing work. This list shall closely resemble the list submitted with the Preliminary Systematic Procedures report with any discrepancies accounted for.
- E. Report systems for excessive sound and vibration per the sound and vibration inspection and testing portions of this specification.
- F. Substantial completion of this project will not take place until a satisfactory report is received. The Testing & Balancing Contractor shall respond and correct all deficiencies within seven (7) days of receiving the Engineer's written review of the balancing report. Failure to comply will result in holding retainage of the final payment until all items have been corrected to the satisfaction of the Engineer.
- G. The report shall be signed by the supervising registered professional engineer and affixed with their registration stamp, signed and dated in accordance with state law.

3.15 GUARANTEE OF WORK:

- A. The Testing & Balancing Contractor shall guarantee the accuracy of the tests and balance for a period of 90 days from date of final acceptance of the test and balance report. During this period, the Testing & Balancing Contractor shall make personnel available at no cost to the Owner to correct deficiencies that may become apparent in the system balance.

END OF SECTION 15990