SECTION 230593 - TESTING, ADJUSTING, AND BALANCING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes Testing, Adjusting, and Balancing, (TAB) to produce design objectives for the following:

1. Air Systems:
   a. Constant-volume air systems.
   b. Variable-air-volume systems.
   c. Multizone systems.

2. Hydronic Piping Systems:
   a. Constant-flow systems.
   b. Variable-flow systems.

3. HVAC equipment quantitative-performance settings.
5. Existing systems TAB.
6. Verifying that duct-mounted smoke detectors, smoke dampers, combination fire/smoke dampers are installed per the manufacturer's instructions and are operating correctly.
7. [Witnessing and Certifying the Operational Test of the Refrigerant Monitoring System.]
8. Reporting results of activities and procedures specified in this Section.

B. The form that provides TAB services shall be under contract directly with the General Contractor and shall not be a subcontractor to the Mechanical Contractor, nor an affiliate of the Mechanical Contractor.

1.2 DEFINITIONS

C. CTI: Cooling Tower Institute.
E. SMACNA: Sheet Metal and Air Conditioning Contractors’ National Association.
F. TAB: Testing, Adjusting, and Balancing.
1.3 SUBMITTALS

A. Certified TAB Reports: Submit copies of reports prepared, as specified in this Section, on approved forms certified by TAB firm.

B. Engineers Report: Submit copies of the Professional Mechanical Engineer’s report, as specified in this Section, certifying the proper operation of smoke control devices and air-moving device shut-downs.

C. Warranties specified in this Section.

1.4 QUALITY ASSURANCE

A. TAB Firm Qualifications: Engage a TAB firm certified by AABC, NEBB, or TABB.

B. Approved TAB firms:

1. Arizona Air Balance.
3. Environmental Test and Balancing, Inc.
4. General Air Control
6. Precisionaire, Inc.
7. QC Analytical.
8. TAB Technology, Inc.

C. Certification of TAB Reports: Certify TAB field data reports. This certification includes the following:

1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
2. Certify that TAB team complied with approved TAB plan and the procedures specified and referenced in this Specification.


E. Instrumentation Type, Quantity, and Accuracy: As described in AABC national standards or NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems," Section II, "Required Instrumentation for NEBB Certification", or TABB’s “National Standards for Environmental Systems Balance.”

F. Instrumentation Calibration: Calibrate instruments at least every six months or more frequently if required by the instrument manufacturer.

1.5 PROJECT CONDITIONS
A. Partial Owner Occupancy: Owner may occupy completed areas of building before Substantial Completion. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

1.6 COORDINATION

A. Coordinate the efforts of factory-authorized service representatives for systems and equipment, HVAC controls installers, and other mechanics to operate HVAC systems and equipment to support and assist TAB activities.

B. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

1.7 WARRANTY

A. Special Guarantee: Provide a guarantee on AABC, NEBB, or TABB forms stating that AABC, NEBB, or TABB will assist in completing the requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Guarantee includes the following provisions:

1. The certified TAB firm has tested and balanced systems according to the Contract Documents.
2. Systems are balanced to optimum performance capabilities within design and installation limits.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment.

1. Verify that air balancing devices, such as manual volume dampers, are required by the Contract Documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.

2. [Verify that hydronic balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, and balancing valves, are required by the Contract Documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.]

B. Examine approved submittal data of HVAC systems and equipment.

C. Examine Project Record Documents described in Division 1 Section "Project Record Documents."
D. Examine air-systems equipment performance data including fan curves. 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. Calculate system effect factors to reduce performance ratings of HVAC air-systems equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," Sections 7 through 10; or in SMACNA's "HVAC Systems--Duct Design," Sections 5 and 6. Compare this data with the design data and installed conditions.

E. Examine hydronic equipment performance data including pump curves. 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. Calculate system effect factors to reduce performance ratings of HVAC hydronic equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. Compare this data with the design data and installed conditions.

F. Examine system and equipment installations to verify that they are complete and that testing, cleaning, adjusting, and start-up specified in individual Sections have been performed.

G. Examine system and equipment test reports.

H. Examine HVAC air systems and equipment installations to verify that indicated balancing devices, such as manual volume dampers, are properly installed, and that their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

I. Examine HVAC hydronic system and equipment installations to verify that indicated balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, and balancing valves, are properly installed, and that their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

J. Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing.

K. Examine HVAC equipment to ensure that clean filters have been installed, bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.

L. Examine fan coil units, terminal units, such as variable-air-volume boxes, to verify that they are accessible and their controls are connected and functioning.

M. Visually examine underfloor plenums used for supply air to verify that pipe penetrations and other holes not required for airflow are sealed.

N. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

O. Examine strainers for clean screens and proper perforations.

P. Examine three-way valves for proper installation for their intended function of diverting or mixing fluid flows.
Q. [Examine open-loop-system pumps to ensure absence of entrained air in the suction piping.]

R. Examine equipment for installation and for properly operating safety interlocks and controls.

S. Examine Smoke Control Devices:

1. Duct mounted smoke detectors:
   a. Verify sensor length and mounting location is per the manufacturer’s instructions.
   b. Verify the detector is installed per the manufacturer’s instructions.
   c. Verify the velocity of the air in the duct at the sensor tube location is within the manufacturer’s recommended range.
   d. Verify pressure drop across the detector is within the manufacturer’s recommended range.

2. Smoke dampers and combination fire/smoke dampers:
   a. Verify the dampers are installed per the manufacturer’s instructions.
   b. Verify that power and control wiring has been connected to the damper per the manufacturer’s instructions.
   c. Verify the damper opens and closes smoothly and completely.

T. Report deficiencies discovered before and during performance of TAB procedures to Engineer and Contractor. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.2 PREPARATION

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

B. Complete system readiness checks and prepare system readiness 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 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.

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC’s "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems", NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems", or TABB’s “HVAC Systems-Testing, Adjusting, and Balancing” and this Section.
B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed. Restore vapor barrier and finish according to insulation Specifications for this Project.

C. Mark equipment and balancing device settings with paint or other suitable, permanent identification material, including damper-control positions, [valve position indicators,] fan-speed-control levers, and similar controls and devices, to show final settings.

D. Close or plug all probe holes and test ports after testing and balancing.

3.4 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.

B. For variable-air-volume systems, develop a plan to simulate diversity.

C. Determine the best locations in main and branch ducts for accurate duct airflow measurements.

D. Check airflow patterns from the outside-air louvers and dampers and the return- and exhaust-air dampers, through the supply-fan discharge and mixing dampers.

E. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

F. Verify that motor starters are equipped with properly sized thermal protection.

G. Check dampers for proper position to achieve desired airflow path.

H. Check for airflow blockages.

I. Check condensate drains for proper connections and functioning.

J. Check for proper sealing of air-handling unit components.

K. Check for proper sealing of air duct system.

3.5 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure fan static pressures to determine actual static pressure as follows:

   a. Measure outlet static pressure as far downstream from the fan as practicable and upstream from restrictions in ducts such as elbows and transitions.

   b. Measure static pressure directly at the fan outlet or through the flexible connection.

   c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from flexible connection and downstream from duct restrictions.
d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

2. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.

a. Simulate dirty filter operation and record the point at which maintenance personnel must change filters.

3. Measure static pressures entering and leaving other devices such as sound traps, heat recovery equipment, and air washers, under final balanced conditions.

4. Compare design data with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur. Recommend corrective action to align design and actual conditions.

5. Adjust fan speed using adjustable pulleys, VFD’s, or other motor speed control devices, where provided, to achieve design airflows.

6. If equipment modifications are required, e.g., sheave changes to adjust fan speed, obtain approval from Architect prior to making such modifications. Recommend adjustments to pulley sizes, motor sizes, and electrical connections to accommodate fan-speed changes.

7. 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 modes to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.

1. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved.

a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.

2. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

C. Measure terminal outlets and inlets without making adjustments.

1. Measure terminal outlets using a direct-reading hood or outlet manufacturer’s written instructions and calculating factors.

D. Adjust terminal outlets and inlets for each space to indicated airflows within specified tolerances of indicated values.

1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.

2. Adjust patterns of adjustable outlets for proper distribution without drafts.
3.6 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

A. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a maximum set-point 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.

B. Pressure-Independent, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set outside-air dampers at minimum, and return- and exhaust-air dampers at a position that simulates full-cooling load.
2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
3. Measure total system airflow. Adjust to within indicated airflow.
4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow as described for constant-volume air systems.
   a. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.
6. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.
7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.
8. Record the final fan performance data.

C. Pressure-Dependent, Variable-Air-Volume Systems without Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Balance systems similar to constant-volume air systems.
2. Set terminal units and supply fan at full-airflow condition.
3. Adjust inlet dampers of each terminal unit to indicated airflow and verify operation of the static-pressure controller. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
4. Readjust fan airflow for final maximum readings.
5. Measure operating static pressure at the sensor that controls the supply fan, if one is installed, and verify operation of the static-pressure controller.
6. Set supply fan at minimum airflow if minimum airflow is indicated. Measure static pressure to verify that it is being maintained by the controller.
7. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow as described for constant-volume air systems.
a. If air outlets are out of balance at minimum airflow, report the condition but leave the outlets balanced for maximum airflow.

8. Measure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.

D. Pressure-Dependent, Variable-Air-Volume Systems with Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:

1. Set system at maximum indicated airflow by setting the required number of terminal units at minimum airflow. Select the reduced airflow terminal units so they are distributed evenly among the branch ducts.
2. Adjust supply fan to maximum indicated airflow with the variable-airflow controller set at maximum airflow.
3. Set terminal units at full-airflow condition.
4. Adjust terminal units starting at the supply-fan end of the system and continuing progressively to the end of the system. Adjust inlet dampers of each terminal unit to indicated airflow. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
5. Adjust terminal units for minimum airflow.
6. Measure static pressure at the sensor.
7. Measure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.

3.7 PROCEDURES FOR MULTIZONE SYSTEMS

A. Set unit at full flow through the cooling coil if coil has that capacity.

B. Adjust each zone damper to indicated airflow.

3.8 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

A. Prepare test reports with pertinent design data and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against approved pump flow rate. Correct variations that exceed plus or minus 5 percent.

B. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:

1. Open all manual valves for maximum flow.
2. Check rating of system relief valve(s).
3. Check makeup-water-station pressure gage for adequate pressure for highest vent.
4. Check flow-control valves for specified sequence of operation and set at indicated flow.
5. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type unless several terminal valves are kept open.
6. Set system controls so automatic valves are wide open to heat exchangers.
7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.9 PROCEDURES FOR HYDRONIC SYSTEMS

A. Measure water flow at pumps. Use the following procedures, except for positive-displacement pumps:

1. 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.
2. Check system resistance. With all valves open, read pressure differential across the pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until indicated water flow is achieved.
3. 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 amperage exceeds motor nameplate amperage.

B. Set calibrated balancing valves, if installed, at calculated presettings.

C. Measure flow at all stations and adjust, where necessary, to obtain first balance.

1. System components that have Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.

D. Measure flow at main balancing station and set main balancing device to achieve flow that is 5 percent greater than indicated flow.

E. Adjust balancing stations to within specified tolerances of indicated flow rate as follows:

1. Determine the balancing station with the highest percentage over indicated flow.
2. Adjust each station in turn, beginning with the station with the highest percentage over indicated flow and proceeding to the station with the lowest percentage over indicated flow.
3. Record settings and mark balancing devices.

F. Measure pump flow rate and make final measurements of pump amperage, voltage, rpm, pump heads, and systems' pressures and temperatures including outdoor-air temperature.

G. Measure the differential-pressure control valve settings existing at the conclusions of balancing.

3.10 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

A. Balance systems with automatic two- and three-way control valves by setting systems at maximum flow through heat-exchange terminals and proceed as specified above for hydronic systems.

3.11 PROCEDURES FOR MOTORS
A. Motors, 1/6 HP and Larger: Test at final balanced conditions and record the following data:

1. Manufacturer.
4. Efficiency rating.
5. Nameplate and measured voltage, each phase.
6. Nameplate and measured amperage, each phase.
7. Starter thermal-protection-element rating.

B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass for the controller to prove proper operation. Record observations, including controller manufacturer, model and serial numbers, and nameplate data.

3.12 PROCEDURES FOR CHILLERS

A. Balance water flow through each evaporator and condenser to within specified tolerances of indicated flow with all pumps operating. With only one chiller operating in a multiple chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:

1. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
2. If water-cooled chillers, condenser-water entering and leaving temperatures, pressure drop, and water flow.
3. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
4. Power factor if factory-installed instrumentation is furnished for measuring kilowatt.
5. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatt.
7. If air-cooled chillers, verify condenser-fan rotation and record fan and motor data including number of fans and entering- and leaving-air temperatures.

3.13 PROCEDURES FOR COOLING TOWERS

A. Balance condenser-water flow to each tower cell. Adjust make-up water level control device. Verify that makeup and blowdown systems are fully operational after tests and before leaving the equipment. Measure and record the following data for each cooling tower:

1. Condenser-water flow to each cell of the cooling tower.
2. Entering- and leaving-water temperatures.
3. Wet- and dry-bulb temperatures of entering air.
4. Wet- and dry-bulb temperatures of leaving air.
5. Tower-water flow rate recirculating through closed-circuit cooling towers.
6. Pump discharge pressure on closed-circuit cooling towers.
7. Adjust water level and feed rate of makeup-water system.

3.14 PROCEDURES FOR CONDENSING/OUTDOOR UNITS
A. Verify proper rotation of fans.
B. Measure entering- and leaving-air temperatures.
C. Record compressor and fan motor data.

3.15 PROCEDURES FOR BOILERS
A. If hydronic, measure entering- and leaving-water temperatures and water flow.
B. If steam, measure entering-water temperature and flow and leaving steam pressure, and temperature.
C. If forced draft, record blower motor data.

3.16 PROCEDURES FOR ELECTRIC HUMIDIFIERS
A. Record nameplate and measured voltage, each phase, under full load conditions.
B. Record nameplate and measured amperage, each phase, under full load conditions.
C. Verify operation of blower, if equipped.
D. Verify operation of makeup water and blowdown valves.

3.17 PROCEDURES FOR HEAT-TRANSFER COILS
A. Water Coils: Measure and record the following data for each coil:
   1. Entering- and leaving-water temperature.
   2. Water flow rate.
   3. Water pressure drop.
   4. Dry-bulb temperature of entering and leaving air.
   5. Wet-bulb temperature of entering and leaving air for cooling coils.
   6. Airflow.
   7. Air pressure drop.
B. Electric-Heating Coils: Measure and record the following data for each coil:
   1. Airflow.
   2. Entering- and leaving-air temperature at full load.
   3. Nameplate voltage and amperage input of each phase.
   4. Voltage and amperage input of each phase at full load and at each incremental stage.
   5. Calculated kilowatt at full load.
   6. Fuse or circuit-breaker rating for overload protection.
C. Refrigerant Coils: Measure and record the following data for each coil:
   1. Dry-bulb temperature of entering and leaving air.
   2. Wet-bulb temperature of entering and leaving air.
3. Airflow.
4. Air pressure drop.
5. Refrigerant suction pressure and temperature.

3.18 PROCEDURES FOR HEAT-EXCHANGERS

A. Water to Water: Measure and record the following data for each side of the heat exchanger:
   1. Entering- and leaving-water temperature.
   2. Water flow rate.
   3. Water pressure drop.

3.19 PROCEDURES FOR TEMPERATURE MEASUREMENTS

A. During TAB, report the need for adjustment in temperature regulation within the automatic temperature-control system.
B. Measure outside-air, wet- and dry-bulb temperatures.

3.20 PROCEDURES FOR COMMERCIAL KITCHEN HOODS

A. Measure, adjust, and record the airflow of each kitchen hood. For kitchen hoods designed with integral makeup air, measure and adjust the exhaust and makeup airflow. Measure airflow by duct Pitot-tube traverse. If a duct Pitot-tube traverse is not possible, provide an explanation in the report of the reason(s) why and also the reason why the method used was chosen.
   1. Install welded test ports in the sides of the exhaust duct for the duct Pitot-tube traverse. Install each test port with a threaded cap that is liquid tight.
B. After balancing is complete, do the following:
   1. Measure and record the static pressure at the hood exhaust-duct connection.
   2. Measure and record the hood face velocity. Make measurements at multiple points across the face of the hood. Perform measurements at a maximum of 12 inches between points and between any point and the perimeter. Calculate the average of the measurements recorded. Verify that the hood average face velocity complies with the Contract Documents and governing codes.
   3. Check the hood for capture and containment of smoke using a smoke emitting device. Observe the smoke pattern. Make adjustments to room airflow patterns to achieve optimum results.
C. Report deficiencies.

3.21 PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS

A. Before performing testing and balancing of existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished.
   1. New filters are installed.
2. Coils are clean and fins combed.
3. Drain pans are clean.
4. Fans are clean.
5. Bearings and other parts are properly lubricated.
6. [Strainers are clean.]
7. Deficiencies noted in the preconstruction report are corrected.

B. Perform testing and balancing of existing systems as directed in preceding Articles.

3.22 PROCEDURES FOR TESTING SMOKE CONTROL DEVICES

A. Record manufacturer and model number for each smoke detector, smoke damper, combination fire/smoke damper, and damper actuator.

B. Duct Mounted Smoke Detectors:
   1. Verify the proper operation of the smoke detector using a test gas, “canned smoke”, acceptable to the Authorities Having Jurisdiction. (Magnets are not acceptable.)
   2. Verify activation of the smoke detector closes the appropriate smoke or combination fire/smoke damper and/or de-energizes the appropriate air-moving device(s).
   3. Verify activation of the smoke detector is shown by the fire alarm system where monitoring of the detector is required.

C. Smoke and Combination Fire/Smoke Dampers: Verify dampers controlled by a Total Coverage Smoke Detection System operate correctly on a signal from the system.

D. Air-Moving Device Shut-down: Verify air-moving device(s) that are to be de-energized by a Total Coverage Smoke Detection System de-energize on a signal from the system.

E. After all smoke control devices have been installed, the TAB firm shall engage the services of a Professional Mechanical Engineer, registered in the State of Arizona, to witness the operation of each smoke control device and air-moving device shut-downs. The Professional Mechanical Engineer shall submit a signed and sealed report attesting to the proper operation of the smoke control devices and air-moving device shut-downs.

3.23 [PROCEDURES FOR TESTING REFRIGERANT MONITORS]

A. Witness the Operational Test of the refrigerant monitor.

B. Verify the system performs the actions listed in the Sequence of Control.

C. Provide a signed statement on company letterhead in the Certified TAB Report that the Operational Test was completed successfully. Include the following:
   1. Name and company of person conducting the test.
   2. Time and date of the test(s).
   3. Concentrations and type of refrigerant used.
   4. Statement that the test was completed and the system operates as specified.
   5. Name and signature of witness.
3.24 TOLERANCES

A. Set HVAC system airflow and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans:  Plus 10 to minus 5 percent.
2. Air Outlets and Inlets:  Plus 10 to minus 10 percent.
3. Heating-Water Flow Rate:  Plus 10 to minus 10 percent.
4. Cooling-Water Flow Rate:  Plus 10 to minus 5 percent.
5. Hydronic Pumps:  Plus 10 to minus 5 percent.

3.25 CERTIFIED TAB REPORT

A. General:  Typewritten, or computer printout, on standard bond paper, in three-ring binder, tabulated and divided into sections by tested and balanced systems.

B. Include a certification sheet in front of binder signed and sealed by the certified testing and balancing supervisor.

C. Include a list of instruments used for procedures, along with proof of calibration.

D. 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. Manufacturer’s installation instructions for smoke and combination fire/smoke dampers, and duct mounted smoke detectors.
6. Other information relative to equipment performance, but do not include Product Data.

E. General Report Data:  In addition to form titles and entries, include the following data in the final report, as applicable:

1. Title page.
2. Name and address of TAB firm.
3. Project name.
4. Project location.
5. Architect’s name and address.
6. Engineer’s name and address.
7. Contractor’s name and address.
9. Signature of TAB firm 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. Indicated versus final performance.
   b. Notable characteristics of systems.

12. Nomenclature sheets for each item of equipment.
13. Data for HVAC equipment, including manufacturer, model number, serial number, type and size.
14. Notes to explain why certain final data in the body of reports varies from indicated values.
15. Test conditions including the following:
   a. Settings for outside-, return-, and exhaust-air dampers.
   b. Conditions of filters.
   c. Face and bypass damper settings at coils.
   d. Sheave and belt sizes for belt-driven equipment.
   e. Settings for supply-air, static-pressure controller.
   f. Other system operating conditions that affect performance.

F. System Diagrams: Include schematic layouts or reduced scale plans of air and hydronic distribution systems. Include the following:
   1. Quantities of outside, supply, return, and exhaust airflows.
   2. Duct, outlet, and inlet sizes.
   3. [Water and steam flow rates.]
   4. [Pipe and valve sizes and locations.]
   5. Terminal units.

G. TAB Data:
   1. Results of TAB procedures on standard forms. Indicate “NA” (Not Applicable) in unused fields of standard forms. Do not delete unused fields.

H. System Diagrams: Include reduced-scale plans with mechanical equipment and air outlet designations corresponding to those in the TAB Data.

END OF SECTION