SECTION 230593 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

1. GENERAL
	* + 1. RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

* + - * 1. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
			1. SUMMARY
				1. Section Includes:

Testing, Adjusting, and Balancing of Air Systems:

Constant-volume air systems.

Dual-duct systems.

Variable-air-volume systems.

Multizone systems.

Induction-unit systems.

Testing, Adjusting, and Balancing of Hydronic Piping Systems:

Constant-flow hydronic systems.

Variable-flow hydronic systems.

Primary-secondary hydronic systems.

Testing, adjusting, and balancing of fuel oil systems for HVAC.

Testing, adjusting, and balancing of steam and condensate piping systems.

Testing, adjusting, and balancing of equipment.

Retain first subparagraph below for existing projects requiring testing and balancing. Indicate requirements on Drawings to define scope of existing systems to be TAB.

Testing, adjusting, and balancing of existing HVAC systems and equipment.

Procedures for exhaust hoods.

Sound tests.

Vibration tests.

Duct leakage tests verification.

Pipe leakage tests verification.

UFAD plenum leakage tests verification.

HVAC-control system verification.

Smoke-control system tests.

Stair-pressurization system tests.

Elevator-pressurization system tests.

* + - 1. DEFINITIONS

Retain definition(s) remaining after this Section has been edited.

* + - * 1. AABC: Associated Air Balance Council.
				2. NEBB: National Environmental Balancing Bureau.
				3. TAB: Testing, adjusting, and balancing.
				4. TABB: Testing, Adjusting, and Balancing Bureau.
				5. TAB Specialist: An independent entity meeting qualifications to perform TAB work.
				6. TDH: Total dynamic head.
				7. UFAD: Underfloor air distribution.
			1. PREINSTALLATION MEETINGS

Retain "TAB Conference" Paragraph below if HVAC work is complex enough to justify a conference.

* + - * 1. TAB Conference: Conduct a TAB conference at [**Project site**] <**Insert location**> after approval of the TAB strategies and procedures plan, to develop a mutual understanding of the details. Provide a minimum of [**14**] <**Insert number**> days' advance notice of scheduled meeting time and location.

Minimum Agenda Items:

Coordinate requirements in subparagraphs below with Section 013100 "Project Management and Coordination."

The Contract Documents examination report.

The TAB plan.

Needs for coordination and cooperation of trades and subcontractors.

Proposed procedures for documentation and communication flow.

If needed, insert list of conference participants not mentioned in Section 013100 "Project Management and Coordination."

* + - 1. QUALITY ASSURANCE

Retain "TAB Specialists Qualifications, Certified by AABC" Paragraph below to require an AABC-certified TAB specialist. AABC-certified companies are independently owned, meaning the Contractor does not share in ownership that could be perceived by some as a conflict of interest.

* + - * 1. TAB Specialists Qualifications, Certified by AABC:

TAB Field Supervisor: Employee of the TAB specialist and certified by AABC.

TAB Technician: Employee of the TAB specialist and certified by AABC.

Retain "TAB Specialists Qualifications, Certified by (NEBB) (or) (TABB)" Paragraph below to require NEBB- or TABB-certified TAB specialists.

* + - * 1. TAB Specialists Qualifications, Certified by [**NEBB**] [**or**] [**TABB**]:

TAB Field Supervisor: Employee of the TAB specialist and certified by [**NEBB**] [**or**] [**TABB**].

TAB Technician: Employee of the TAB specialist and certified by [**NEBB**] [**or**] [**TABB**].

* + - * 1. Instrumentation Type, Quantity, Accuracy, and Calibration: Comply with requirements in ASHRAE 111, Section 4, "Instrumentation."

Retain "ASHRAE/IES 90.1 Compliance" Paragraph below to require compliance with ASHRAE/IES 90.1.

* + - * 1. ASHRAE/IES 90.1 Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6.7.2.3 - "System Balancing."
				2. Code and AHJ Compliance: TAB is required to comply with governing codes and requirements of authorities having jurisdiction.
			1. FIELD CONDITIONS

Retain "Full Owner Facility Occupancy" or "Partial Owner Facility Occupancy" Paragraph below. Delete article if there will be no occupancy during TAB work.

* + - * 1. Full Owner Facility Occupancy: Owner Facility will occupy the site and existing building during entire TAB period. Cooperate with Director’s Representative Owner during TAB operations to minimize conflicts with Owner's Facility's operations.

Retain "Partial Owner Facility Occupancy" Paragraph below if Owner Facility might occupy completed areas of building.

* + - * 1. Partial Owner Facility Occupancy: Owner Facility may occupy completed areas of building before Substantial Completion. Cooperate with Owner Facility during TAB operations to minimize conflicts with Owner's Facility's operations.
1. PRODUCTS (Not Applicable)
2. EXECUTION
	* + 1. TAB SPECIALISTS

Retain this article and list of TAB specialists to limit Contractor's choice of TAB specialists; delete to allow Contractor to select any TAB specialist meeting qualification requirements.

* + - * 1. Subject to compliance with requirements, [**engage one of the following**] [**available TAB specialists that may be engaged include, but are not limited to, the following**]:

<**Insert TAB specialist's name**>.

* + - 1. EXAMINATION
				1. 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.
				2. Examine installed systems for balancing devices, such as test ports, gauge cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are applicable for intended purpose and are accessible.
				3. Examine the approved submittals for HVAC systems and equipment.

See "Design Data" Article in the Evaluations.

* + - * 1. Examine design data, including HVAC system descriptions, statements of design assumptions for environmental conditions and systems output, and statements of philosophies and assumptions about HVAC system and equipment controls.
				2. Examine ceiling plenums and underfloor air plenums used for HVAC to verify that they are properly separated from adjacent areas and sealed.
				3. Examine equipment performance data, including fan and 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 equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.

* + - * 1. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.
				2. Examine test reports specified in individual system and equipment Sections.
				3. Examine HVAC equipment and verify that bearings are greased, belts are aligned and tight, filters are clean, and equipment with functioning controls is ready for operation.
				4. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.

Retain first paragraph below to require TAB to examine strainers. Examination of strainers can also be accomplished by installers. Coordinate requirement with other Sections.

* + - * 1. Examine temporary and permanent strainers. Verify that temporary strainer screens used during system cleaning and flushing have been removed and permanent strainer baskets are installed and clean.
				2. Examine control valves for proper installation for their intended function of isolating, throttling, diverting, or mixing fluid flows.
				3. Examine heat-transfer coils for correct piping connections and for clean and straight fins.
				4. Examine system pumps to ensure absence of entrained air in the suction piping.
				5. Examine operating safety interlocks and controls on HVAC equipment.
				6. Examine control dampers for proper installation for their intended function of isolating, throttling, diverting, or mixing air flows.
				7. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.
			1. PREPARATION
				1. Prepare a TAB plan that includes the following:

Equipment and systems to be tested.

Strategies and step-by-step procedures for balancing the systems.

Instrumentation to be used.

Sample forms with specific identification for all equipment.

* + - * 1. Perform system-readiness checks of HVAC systems and equipment to verify system readiness for TAB work. Include, at a minimum, the following:

Airside:

Verify that leakage and pressure tests on air distribution systems have been satisfactorily completed.

Duct systems are complete with terminals installed.

Volume, smoke, and fire dampers are open and functional.

Clean filters are installed.

Fans are operating, free of vibration, and rotating in correct direction.

Variable-frequency controllers' startup is complete and safeties are verified.

Automatic temperature-control systems are operational.

Ceilings are installed.

Windows and doors are installed.

Suitable access to balancing devices and equipment is provided.

Hydronics:

Verify leakage and pressure tests on water distribution systems have been satisfactorily completed.

Piping is complete with terminals installed.

Water treatment is complete.

Systems are flushed, filled, and air purged.

Strainers are pulled and cleaned.

Control valves are functioning in accordance with the sequence of operation.

Shutoff and balance valves have been verified to be 100 percent open.

Pumps are started and proper rotation is verified.

Pump gauge connections are installed directly at pump inlet and outlet flanges or in discharge and suction pipe prior to valves or strainers.

Variable-frequency controllers' startup is complete and safeties are verified.

Suitable access to balancing devices and equipment is provided.

* + - 1. GENERAL PROCEDURES FOR TESTING AND BALANCING

LEED 2009 Prerequisite IEQ 1, "Indoor Environmental Quality," and LEED v4 Indoor Environmental Quality Prerequisite, "Minimum Indoor Air Quality Performance," require compliance with requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing." ASHRAE 62.1 requires that ventilation systems be balanced in accordance with ASHRAE 111 or SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing" or be equivalent at least to extent necessary to verify compliance with the standard. AABC's "National Standards for Total System Balance" meet or exceed this requirement.

* + - * 1. Perform testing and balancing procedures on each system in accordance with the procedures contained in [**AABC's "National Standards for Total System Balance"**] [**ASHRAE 111**] [**NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems"**] and in this Section.
				2. Cut insulation, ducts, pipes, and equipment casings for installation of test probes to the minimum extent necessary for TAB procedures.

Retain one of first two subparagraphs below.

After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.

After testing and balancing, install test ports and duct access doors that comply with requirements in Section 233300 "Air Duct Accessories."

Where holes for probes are required in piping or hydronic equipment, install pressure and temperature test plugs to seal systems.

Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish in accordance with Section 230713 "Duct Insulation," Section 230716 "HVAC Equipment Insulation," and Section 230719 "HVAC Piping Insulation."

* + - * 1. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.
				2. Take and report testing and balancing measurements in [**inch-pound (IP)**] [**and**] [**metric (SI)**] units.
			1. TESTING, ADJUSTING, AND BALANCING OF HVAC EQUIPMENT
				1. Test, adjust, and balance HVAC equipment indicated on Drawings, including, but not limited to, the following:

Retain any of 40 subparagraphs below as applicable to Project.

Motors.

Pumps.

Fans and ventilators.

Air curtains.

Terminal units.

Commercial kitchen hoods.

Boilers.

Deaerators.

Furnaces.

Radiant heaters.

Unit heaters.

Solar collectors.

Heat exchangers.

Condensing units.

Condensers.

Water chillers.

Cooling towers.

Energy-recovery units.

Air-handling units.

Heating and ventilating units.

Rooftop air-conditioning units.

Heating-only makeup air units.

Dedicated outdoor-air units.

Packaged air conditioners.

Self-contained air conditioners.

Computer-room air conditioners.

Split-system air conditioners.

Variable-refrigerant-flow systems.

Heat pumps.

Valance heating and cooling units.

Chilled beams.

Coils.

Fan coil units.

Unit ventilators.

Radiators.

Convectors.

Finned-tube radiation heaters.

Radiant-heating [**cables**] [**piping**] [**and**] [**panels**].

Humidifiers.

Dehumidification units.

<**Insert equipment**>.

* + - 1. GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS
				1. 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.
				2. Prepare schematic diagrams of systems' Record drawings duct layouts.
				3. For variable-air-volume systems, develop a plan to simulate diversity.
				4. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.
				5. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.
				6. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
				7. Verify that motor starters are equipped with properly sized thermal protection.
				8. Check dampers for proper position to achieve desired airflow path.
				9. Check for airflow blockages.
				10. Check condensate drains for proper connections and functioning.
				11. Check for proper sealing of air-handling-unit components.
			2. PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS
				1. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

Measure total airflow.

Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.

Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.

Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.

Measure fan static pressures as follows:

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

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

Measure static pressure across each component that makes up the air-handling system.

Report artificial loading of filters at the time static pressures are measured.

First two subparagraphs below may require changes to installed systems or equipment; these changes may require a Contract Modification.

Review Contractor-prepared shop drawings and Record drawings to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

See the Evaluations for discussion of fan-speed adjustments.

Obtain approval from [**Director’s Representative**] [**Owner**] [**Construction Manager**] [**Commissioning Authority**] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

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 occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

* + - * 1. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.

Measure airflow of submain and branch ducts.

Adjust submain and branch duct volume dampers for specified airflow.

Re-measure each submain and branch duct after all have been adjusted.

* + - * 1. Adjust air inlets and outlets for each space to indicated airflows.

Set airflow patterns of adjustable outlets for proper distribution without drafts.

Measure inlets and outlets airflow.

Adjust each inlet and outlet for specified airflow.

Re-measure each inlet and outlet after they have been adjusted.

* + - * 1. Verify final system conditions.

Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to design if necessary.

Re-measure and confirm that total airflow is within design.

Re-measure all final fan operating data, speed, volts, amps, and static profile.

Mark all final settings.

Test system in economizer mode. Verify proper operation and adjust if necessary.

Measure and record all operating data.

Record final fan-performance data.

* + - 1. PROCEDURES FOR DUAL-DUCT SYSTEMS
				1. Adjust the dual-duct systems as follows:

Verify that the system static pressure sensor is located two-thirds of the distance down the duct from the fan discharge. On systems with separate hot-deck and cold-deck fans, verify the location of the sensor on each deck.

Verify that the system is under static pressure control.

Select the terminal unit that is most critical to the supply-fan airflow. Measure inlet static pressure, and adjust system static pressure control set point, so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.

Calibrate and balance each terminal unit's hot deck and cold deck for maximum and minimum design airflow as follows:

Adjust controls so that terminal is calling for full cooling. Some controllers require starting with minimum set point. Verify calibration procedure for specific project.

Measure airflow and adjust calibration factors as required for design cold-deck maximum airflow and hot-deck minimum airflow. Record calibration factors.

When maximum airflow is correct, balance the air outlets downstream from terminal units.

Adjust controls so that terminal is calling for full heating.

Measure airflow and adjust calibration factors as required for design cold-deck minimum airflow and hot-deck maximum airflow. Record calibration factors. If no minimum calibration is available, note any deviation from design airflow.

After terminals have been calibrated and balanced, test and adjust system for total airflow. Adjust fans to deliver total design airflows within the maximum allowable fan speed listed by fan manufacturer.

Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.

Set terminals for maximum airflow. If system design includes diversity (cooling coil or fan), adjust terminals for maximum and minimum airflow so that connected total matches cooling coil or fan selection and simulates actual load in the building. In systems with separate hot-deck and cold-deck fans, diversity consideration applies to each individual fan.

Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.

Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.

Measure the fan(s) static pressures as follows:

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

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

Measure static pressure across each component that makes up the air-handling system.

Report any artificial loading of filters at the time static pressures are measured.

Set final return and outside airflow to the fan(s) while operating at maximum return airflow and minimum outdoor airflow.

Balance the return-air ducts and inlets.

Verify that all terminal units are meeting design airflow under system maximum flow.

Re-measure the inlet static pressure at the most critical terminal unit, and adjust the system static pressure set point to the most energy-efficient set point to maintain the optimum system static pressure. Record set point and give to controls Contractor.

Verify final system conditions as follows:

Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.

Re-measure and confirm that total airflow is within design.

Re-measure final fan operating data, speed, volts, amps, and static profile.

Mark final settings.

Test system in economizer mode. Verify proper operation and adjust if necessary. Measure and record all operating data.

Verify tracking between supply and return fans.

Record final fan-performance data.

* + - 1. PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS
				1. Adjust the variable-air-volume systems as follows:

Verify that the system static pressure sensor is located two-thirds of the distance down the duct from the fan discharge.

Verify that the system is under static pressure control.

Select the terminal unit that is most critical to the supply-fan airflow. Measure inlet static pressure, and adjust system static pressure control set point so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.

Calibrate and balance each terminal unit for maximum and minimum design airflow as follows:

Adjust controls so that terminal is calling for maximum airflow. Some controllers require starting with minimum airflow. Verify calibration procedure for specific project.

Measure airflow and adjust calibration factor as required for design maximum airflow. Record calibration factor.

When maximum airflow is correct, balance the air outlets downstream from terminal units.

Adjust controls so that terminal is calling for minimum airflow.

Measure airflow and adjust calibration factor as required for design minimum airflow. Record calibration factor. If no minimum calibration is available, note any deviation from design airflow.

On constant volume terminals, in critical areas where room pressure is to be maintained, verify that the airflow remains constant over the full range of full cooling to full heating. Note any deviation from design airflow or room pressure.

After terminals have been calibrated and balanced, test and adjust system for total airflow. Adjust fans to deliver total design airflows within the maximum allowable fan speed listed by fan manufacturer.

Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.

Set terminals for maximum airflow. If system design includes diversity, adjust terminals for maximum and minimum airflow, so that connected total matches fan selection and simulates actual load in the building.

Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.

Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.

Measure fan static pressures as follows:

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

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

Measure static pressure across each component that makes up the air-handling system.

Report any artificial loading of filters at the time static pressures are measured.

Set final return and outside airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

Balance the return-air ducts and inlets.

Verify that terminal units are meeting design airflow under system maximum flow.

Re-measure the inlet static pressure at the most critical terminal unit, and adjust the system static pressure set point to the most energy-efficient set point to maintain the optimum system static pressure. Record set point and give to controls Contractor.

Verify final system conditions as follows:

Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.

Re-measure and confirm that total airflow is within design.

Re-measure final fan operating data, speed, volts, amps, and static profile.

Mark final settings.

Test system in economizer mode. Verify proper operation and adjust if necessary. Measure and record all operating data.

Verify tracking between supply and return fans.

* + - 1. PROCEDURES FOR MULTIZONE SYSTEMS
				1. Position the unit's automatic zone dampers for maximum flow through the cooling coil.
				2. The procedures for multizone systems will utilize the zone balancing dampers to achieve the indicated airflow within the zone.
				3. After balancing, place the unit's automatic zone dampers for maximum heating flow. Retest zone airflows and record any variances.
				4. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

Measure total airflow.

Set outside-air, return-air and relief-air dampers for proper position that simulates minimum outdoor air conditions.

Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.

Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.

Measure fan static pressures as follows:

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

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

Measure static pressure across each component that makes up the air-handling system.

Report artificial loading of filters at the time static pressures are measured.

First two subparagraphs below may require changes to installed systems or equipment; these changes may require a Contract Modification.

Review Record drawings to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

See the Evaluations for discussion of fan-speed adjustments.

Obtain approval from [**Director’s Representative**] [**Owner**] [**Construction Manager**] [**Commissioning Authority**] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

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 occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

* + - * 1. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.

Measure airflow of submain and branch ducts.

Adjust submain and branch duct volume dampers for specified airflow.

Re-measure each submain and branch duct after all have been adjusted.

* + - * 1. Adjust air inlets and outlets for each space to indicated airflows.

Set airflow patterns of adjustable outlets for proper distribution without drafts.

Measure inlet and outlet airflow.

Adjust each inlet and outlet for specified airflow.

Re-measure each inlet and outlet after they have been adjusted.

* + - * 1. Verify final system conditions.

Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.

Re-measure and confirm that total airflow is within design.

Re-measure all final fan operating data, speed, volts, amps, and static profile.

Mark all final settings.

Test system in economizer mode. Verify proper operation and adjust if necessary.

Measure and record all operating data.

Record final fan-performance data.

* + - 1. PROCEDURES FOR INDUCTION-UNIT SYSTEMS
				1. Balance primary-air risers by measuring static pressure at the nozzles of the top and bottom units of each riser, to determine which risers must be throttled. Adjust risers to indicated airflow within specified tolerances.
				2. Adjust each induction unit.
				3. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

Measure total airflow.

Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.

Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses close to the fan and prior to any outlets, to obtain total airflow.

Where duct conditions are unsuitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.

Measure fan static pressures as follows:

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

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

Measure static pressure across each component that makes up the air-handling system.

Report artificial loading of filters at the time static pressures are measured.

First two subparagraphs below may require changes to installed systems or equipment; these changes may require a Contract Modification.

Review Record drawings to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

See the Evaluations for discussion of fan-speed adjustments.

Obtain approval from [**Director’s Representative**] [**Owner**] [**Construction Manager**] [**Commissioning Authority**] for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

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 occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

* + - * 1. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.

Measure airflow of submain and branch ducts.

Adjust submain and branch duct volume dampers for specified airflow.

Re-measure each submain and branch duct after all have been adjusted.

* + - * 1. Balance airflow to each induction unit by measuring the nozzle pressure and comparing it to the manufacturer's published data for nozzle pressure versus cfm. Adjust the unit's inlet damper to achieve the required nozzle pressure for design cfm.
				2. Verify final system conditions.

Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to match design if necessary.

Re-measure and confirm that total airflow is within design.

Re-measure all final fan operating data, speeds, volts, amps, and static profile.

Mark all final settings.

Test system in economizer mode. Verify proper operation and adjust if necessary.

Measure and record all operating data.

Record final fan-performance data.

* + - 1. GENERAL PROCEDURES FOR HYDRONIC SYSTEMS
				1. Prepare test reports for pumps, coils, and other equipment. Obtain approved submittals and manufacturer-recommended testing procedures. Crosscheck the summation of required coil and equipment flow rates with pump design flow rate.
				2. Prepare schematic diagrams of systems' Record drawings piping layouts.
				3. In addition to requirements in "Preparation" Article, prepare hydronic systems for testing and balancing as follows:

Check expansion tank for proper setting.

Check highest vent for adequate pressure.

Check flow-control valves for proper position.

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

Verify that motor controllers are equipped with properly sized thermal protection.

Check that air has been purged from the system.

* + - * 1. Measure and record upstream and downstream pressure of each piece of equipment.
				2. Measure and record upstream and downstream pressure of pressure-reducing valves.
				3. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.

Check settings and operation of each safety valve. Record settings.

* + - 1. PROCEDURES FOR CONSTANT-FLOW HYDRONIC SYSTEMS
				1. Adjust pumps to deliver total design flow.

Measure total water flow.

Position valves for full flow through coils.

Measure flow by main flow meter, if installed.

If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.

Measure pump TDH as follows:

Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.

Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.

Convert pressure to head and correct for differences in gauge heights.

Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.

With valves open, read pump TDH. Adjust pump discharge valve until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.

Monitor motor performance during procedures, and do not operate motor in an overloaded condition.

* + - * 1. Adjust flow-measuring devices installed in mains and branches to design water flows.

Measure flow in main and branch pipes.

Adjust main and branch balance valves for design flow.

Re-measure each main and branch after all have been adjusted.

* + - * 1. Adjust flow-measuring devices installed at terminals for each space to design water flows.

Measure flow at terminals.

Adjust each terminal to design flow.

Re-measure each terminal after it is adjusted.

Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.

Perform temperature tests after flows have been balanced.

* + - * 1. For systems with pressure-independent valves at terminals:

Measure differential pressure and verify that it is within manufacturer's specified range.

Perform temperature tests after flows have been verified.

* + - * 1. For systems without pressure-independent valves or flow-measuring devices at terminals:

Measure and balance coils by either coil pressure drop or temperature method.

If balanced by coil pressure drop, perform temperature tests after flows have been verified.

* + - * 1. Verify final system conditions as follows:

Re-measure and confirm that total water flow is within design.

Re-measure final pumps' operating data, TDH, volts, amps, and static profile.

Mark final settings.

* + - * 1. Verify that memory stops have been set.
			1. PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS
				1. 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.
				2. Adjust the variable-flow hydronic system as follows:

Verify that the pressure-differential sensor(s) is located as indicated.

Determine whether there is diversity in the system.

* + - * 1. For systems with no flow diversity:

Adjust pumps to deliver total design flow.

Measure total water flow.

Position valves for full flow through coils.

Measure flow by main flow meter, if installed.

If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.

Measure pump TDH as follows:

Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.

Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.

Convert pressure to head and correct for differences in gauge heights.

Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.

With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.

Monitor motor performance during procedures, and do not operate motor in an overloaded condition.

Adjust flow-measuring devices installed in mains and branches to design water flows.

Measure flow in main and branch pipes.

Adjust main and branch balance valves for design flow.

Re-measure each main and branch after all have been adjusted.

Adjust flow-measuring devices installed at terminals for each space to design water flows.

Measure flow at terminals.

Adjust each terminal to design flow.

Re-measure each terminal after it is adjusted.

Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.

Perform temperature tests after flows have been balanced.

For systems with pressure-independent valves at terminals:

Measure differential pressure and verify that it is within manufacturer's specified range.

Perform temperature tests after flows have been verified.

For systems without pressure-independent valves or flow-measuring devices at terminals:

Measure and balance coils by either coil pressure drop or temperature method.

If balanced by coil pressure drop, perform temperature tests after flows have been verified.

Prior to verifying final system conditions, determine the system pressure-differential set point(s).

If the pump discharge valve was used to set total system flow with variable-frequency controller at 60 Hz, at completion, open discharge valve 100 percent, and allow variable-frequency controller to control system differential-pressure set point. Record pump data under both conditions.

Mark final settings and verify that all memory stops have been set.

Verify final system conditions as follows:

Re-measure and confirm that total flow is within design.

Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.

Mark final settings.

* + - * 1. For systems with flow diversity:

Determine diversity factor.

Simulate system diversity by closing required number of control valves, as approved by Director’s Representative.

Adjust pumps to deliver total design flow.

Measure total water flow.

Position valves for full flow through coils.

Measure flow by main flow meter, if installed.

If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.

Measure pump TDH as follows:

Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.

Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.

Convert pressure to head and correct for differences in gauge heights.

Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.

With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.

Monitor motor performance during procedures, and do not operate motor in an overloaded condition.

Adjust flow-measuring devices installed in mains and branches to design water flows.

Measure flow in main and branch pipes.

Adjust main and branch balance valves for design flow.

Re-measure each main and branch after all have been adjusted.

Adjust flow-measuring devices installed at terminals for each space to design water flows.

Measure flow at terminals.

Adjust each terminal to design flow.

Re-measure each terminal after it is adjusted.

Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.

Perform temperature tests after flows have been balanced.

For systems with pressure-independent valves at terminals:

Measure differential pressure, and verify that it is within manufacturer's specified range.

Perform temperature tests after flows have been verified.

For systems without pressure-independent valves or flow-measuring devices at terminals:

Measure and balance coils by either coil pressure drop or temperature method.

If balanced by coil pressure drop, perform temperature tests after flows have been verified.

Open control valves that were shut. Close a sufficient number of control valves that were previously open to maintain diversity, and balance terminals that were just opened.

Prior to verifying final system conditions, determine system pressure-differential set point(s).

If the pump discharge valve was used to set total system flow with variable-frequency controller at 60 Hz, at completion, open discharge valve 100 percent, and allow variable-frequency controller to control system differential-pressure set point. Record pump data under both conditions.

Mark final settings and verify that memory stops have been set.

Verify final system conditions as follows:

Re-measure and confirm that total water flow is within design.

Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.

Mark final settings.

* + - 1. PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS
				1. Balance the primary circuit flow first.
				2. Balance the secondary circuits after the primary circuits are complete.
				3. Adjust pumps to deliver total design flow.

Measure total water flow.

Position valves for full flow through coils.

Measure flow by main flow meter, if installed.

If main flow meter is not installed, determine flow by pump TDH or known equipment pressure drop.

Measure pump TDH as follows:

Measure discharge pressure directly at the pump outlet flange or in discharge pipe prior to any valves.

Measure inlet pressure directly at the pump inlet flange or in suction pipe prior to any valves or strainers.

Convert pressure to head and correct for differences in gauge heights.

Verify pump impeller size by measuring the TDH with the discharge valve closed. Note the point on manufacturer's pump curve at zero flow, and verify that the pump has the intended impeller size.

With valves open, read pump TDH. Adjust pump discharge valve or speed until design water flow is achieved. If excessive throttling is required to achieve desired flow, recommend pump impellers be trimmed to reduce excess throttling.

Monitor motor performance during procedures, and do not operate motor in an overloaded condition.

* + - * 1. Adjust flow-measuring devices installed in mains and branches to design water flows.

Measure flow in main and branch pipes.

Adjust main and branch balance valves for design flow.

Re-measure each main and branch after all have been adjusted.

* + - * 1. Adjust flow-measuring devices installed at terminals for each space to design water flows.

Measure flow at terminals.

Adjust each terminal to design flow.

Re-measure each terminal after it is adjusted.

Position control valves to bypass the coil, and adjust the bypass valve to maintain design flow.

Perform temperature tests after flows have been balanced.

* + - * 1. For systems with pressure-independent valves at terminals:

Measure differential pressure and verify that it is within manufacturer's specified range.

Perform temperature tests after flows have been verified.

* + - * 1. For systems without pressure-independent valves or flow-measuring devices at terminals:

Measure and balance coils by either coil pressure drop or temperature method.

If balanced by coil pressure drop, perform temperature tests after flows have been verified.

* + - * 1. Verify final system conditions as follows:

Re-measure and confirm that total water flow is within design.

Re-measure final pumps' operating data, TDH, volts, amps, speed, and static profile.

Mark final settings.

* + - * 1. Verify that memory stops have been set.
			1. PROCEDURES FOR STEAM AND CONDENSATE SYSTEMS
				1. Measure and record upstream and downstream pressure of each piece of equipment.
				2. Measure and record upstream and downstream steam pressure of pressure-reducing valves.
				3. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.
				4. Check settings and operation of each safety valve. Record settings.
				5. Verify the operation of each steam trap.
			2. PROCEDURES FOR STEAM-TO-WATER HEAT EXCHANGERS
				1. Adjust and record water flow to within specified tolerances.
				2. Measure and record inlet and outlet water temperatures.
				3. Measure and record inlet steam pressure and condensate outlet pressure.
				4. Check and record settings and operation of safety and relief valves.
			3. PROCEDURES FOR WATER-TO-WATER HEAT EXCHANGERS
				1. Adjust and record water flow to within specified tolerances.
				2. Measure and record inlet and outlet water temperatures.
				3. Measure and record pressure drop.
				4. Check and record settings and operation of safety and relief valves.
			4. PROCEDURES FOR MOTORS
				1. Motors [**1/2**] <**Insert value**> HP and Larger: Test at final balanced conditions and record the following data:

Manufacturer's name, model number, and serial number.

Motor horsepower rating.

Motor rpm.

Phase and hertz.

Nameplate and measured voltage, each phase.

Nameplate and measured amperage, each phase.

Starter size and thermal-protection-element rating.

Service factor and frame size.

* + - * 1. Motors Driven by Variable-Frequency Controllers: Test manual bypass of controller to prove proper operation.
			1. PROCEDURES FOR WATER CHILLERS
				1. Air-Cooled Chillers: Balance water flow through each evaporator 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:

Evaporator-water entering and leaving temperatures, pressure drop, and water flow.

Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.

Power factor if factory-installed instrumentation is furnished for measuring kilowatts.

Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.

Capacity: Calculate in [**tons**] [**kilowatts**] <**Insert units**> of cooling.

Efficiency: Calculate operating efficiency for comparison to submitted equipment.

Verify condenser-fan rotation and record fan and motor data, including number of fans and entering- and leaving-air temperatures.

* + - * 1. Water-Cooled Chillers: 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:

Evaporator-water entering and leaving temperatures, pressure drop, and water flow.

Condenser-water entering and leaving temperatures, pressure drop, and water flow.

Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.

Power factor if factory-installed instrumentation is furnished for measuring kilowatts.

Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.

Capacity: Calculate in [**tons**] [**kilowatts**] <**Insert units**> of cooling.

Efficiency: Calculate operating efficiency for comparison to submitted equipment.

* + - 1. PROCEDURES FOR COOLING TOWERS

Retain "Performance Testing" Paragraph below if field tests are required to certify performance of installed equipment. Include additional requirements to establish acceptance criteria, allowable tolerances, and other requirements needed to comply with a Project-specific test standard. Field performance testing adds cost and is generally not necessary for cooling towers that are certified under the CTI certification program. Consult Director’s Representative to address benefits and cost.

* + - * 1. Performance Testing: Comply with [**CTI ATC-105**] [**Cooling tower "AABC Performance Test" in AABC's "National Standards for Total System Balance"**] <**Insert test procedure**>.
				2. Closed-Circuit Cooling Towers: Balance total condenser-water flows to towers and cells. Measure and record the following data:

Condenser-water flow to each cell of the cooling tower.

Pressure drop through each cell.

Entering- and leaving-water temperatures.

Wet- and dry-bulb temperatures of entering air.

Wet- and dry-bulb temperatures of leaving air.

Barometric pressure, wind speed, and wind direction.

Condenser-water flow rate recirculating through the cooling tower.

Cooling-tower spray pump discharge pressure.

Condenser-water flow through bypass.

Makeup-water flow rate.

Makeup water temperature.

Fan, motor, and motor controller operating data.

Cooling-tower spray pump and motor operating data.

Retain subparagraph below if cooling towers include heaters.

Heater operating data.

* + - * 1. Open-Circuit Cooling Towers: Balance total condenser-water flows to towers and cells. Measure and record the following data:

Condenser-water flow to each cell of the cooling tower.

Pressure at each inlet connection.

Entering- and leaving-water temperatures.

Range.

Makeup-water flow rate.

Makeup water temperature.

Wet- and dry-bulb temperatures of entering air.

Wet- and dry-bulb temperatures of leaving air.

Approach.

Barometric pressure, wind speed, and wind direction.

Fan, motor, and motor controller operating data.

Retain subparagraph below if cooling towers include heaters.

Heater operating data.

* + - 1. PROCEDURES FOR AIR-COOLED CONDENSING UNITS
				1. Verify proper rotation of fan(s).
				2. Measure and record entering- and leaving-air temperatures.
				3. Measure and record entering and leaving refrigerant pressures.
				4. Measure and record operating data of compressor(s), fan(s), and motors.
			2. PROCEDURES FOR AIR-COOLED CONDENSERS
				1. Verify proper rotation of fan(s).
				2. Measure and record entering- and leaving-air temperatures.
				3. Measure and record entering and leaving refrigerant pressures.
				4. Measure and record operating data of fan(s) and motor(s).
			3. PROCEDURES FOR BOILERS
				1. Hydronic Boilers:

Measure and record entering- and leaving-water temperatures.

Measure and record water flow.

Measure and record pressure drop.

[**Measure and**]Record relief valve(s) pressure setting.

Capacity: Calculate in Btu/h (kW) of heating output.

Fuel Consumption: If boiler fuel supply is equipped with flow meter, measure and record consumption.

Efficiency: Calculate operating efficiency for comparison to submitted equipment.

Fan, motor, and motor controller operating data.

* + - * 1. Steam Boilers:

Measure and record entering-water temperature.

Measure and record feedwater flow.

Measure and record leaving-steam pressure and temperature.

[**Measure and**]Record relief valve(s) pressure setting.

Capacity: Calculate in Btu/h (kW) of heating output.

Efficiency: Calculate operating efficiency for comparison to submitted equipment.

Fan, motor, and motor controller operating data.

Retain "Boilers with Flue Gas Economizers" Paragraph below for boilers furnished with flue gas economizers:

* + - * 1. Boilers with Flue Gas Economizers:

Measure and record entering- and leaving-water temperature.

Measure and record water flow rate.

Measure and record water pressure drop.

Heat Recovered: Calculate in Btu/h (kW) of waste heat recovered.

* + - 1. PROCEDURES FOR HEAT-TRANSFER COILS
				1. Measure, adjust, and record the following data for each hydronic coil:

Entering- and leaving-water temperature.

Water flow rate.

Water pressure drop.

Dry-bulb temperature of entering and leaving air.

Wet-bulb temperature of entering and leaving air for cooling coils.

Airflow.

Air pressure drop.

* + - * 1. Measure, adjust, and record the following data for each electric heating coil:

Nameplate data.

Airflow.

Entering- and leaving-air temperature at full load.

Air pressure drop.

Voltage and amperage input of each phase at full load.

Calculated kilowatt at full load.

Fuse or circuit-breaker rating for overload protection.

* + - * 1. Measure, adjust, and record the following data for each steam coil:

Dry-bulb temperature of entering and leaving air.

Airflow.

Inlet steam pressure.

* + - * 1. Measure, adjust, and record the following data for each refrigerant coil:

Dry-bulb temperature of entering and leaving air.

Wet-bulb temperature of entering and leaving air.

Airflow.

Air pressure drop.

Entering and leaving refrigerant pressure and temperatures.

* + - 1. PROCEDURES FOR EXHAUST HOODS
				1. Room Pressure: Measure and record room pressure with respect to atmosphere and adjacent space with hoods in room initially not operating and then with hoods operating.
				2. Makeup Air: Systems supplying source of makeup air to hoods shall be in operation during testing and balancing of exhaust hoods.

Measure and record temperature of makeup air entering hood. If hood makeup air is from multiple sources having different temperatures, measure and record the airflow and temperatures of each source and calculate the weighted average temperature.

Use simulated smoke to observe supply air-distribution air patterns in vicinity of hoods. Consult with hood manufacturer and report conditions that have a detrimental effect on intended capture, containment, and other attributes effecting proper operation.

* + - * 1. Rooms with Multiple Hoods: Test each hood separately, one at a time, and repeat tests with all hoods intended to operate simultaneously by design.
				2. Canopy Hoods: Measure and record the following:

Pressure drop across hood.

Airflow by duct traverse where duct distribution will allow accurate measurement, and calculate hood average face velocity.

Measure velocity across hood face and calculate hood airflow.

Clearly indicate the direction of flow at each point of measurement.

Measure velocity across opening on not less than [**12-inch12-inch (300-mm)**] <**Insert dimension**> centers. Record velocity at each measurement, and calculate average velocity.

Retain "Capture and Containment" Subparagraph below for assurance hood is operating as intended by design.

Capture and Containment: Check each hood for proper capture and containment using a smoke-emitting device. Observe and report performance. Make adjustments to achieve optimum results.

* + - * 1. Laboratory Fume Hoods: Measure and record the following:

Pressure drop across hood.

Airflow by duct traverse where duct distribution will allow accurate measurement, and calculate hood average face velocity. If hood is connected to exhaust duct distribution through an exhaust device with integral airflow measurement, that reading may be used in lieu of a duct traverse.

Face velocity across open hood face and calculate hood airflow.

Clearly indicate the direction of flow at each point of measurement.

Measure velocity across opening on not less than [**6-inch6-inch (150-mm)**] <**Insert dimension**> centers. Record velocity at each measurement, and calculate average velocity.

Retain "Capture and Containment" Subparagraph below for assurance hood is operating as intended by design.

Capture and Containment: Check each hood for proper capture and containment using a smoke-emitting device. Observe and report performance. Make adjustments to achieve optimum results.

Retain "ASHRAE 110 Testing" Subparagraph below for critical applications. Consult Director’s Representative to confirm the need for and extent of ASHRAE 110 tests.

ASHRAE 110 Testing: With room and laboratory fume hood operating at design conditions, perform an "as-installed" performance test of the laboratory fume hood in accordance with ASHRAE 110. Test [**each**] [**indicate extent**] laboratory fume hood and document the test results.

* + - * 1. Kitchen Hoods:

Type 1: Measure and record pressure drop and face velocity of hood filters and slots in accordance with hood manufacturer's instructions. Consult hood manufacturer to determine hood airflow using recorded information.

Type 2: Measure and record airflow by duct traverse.

Retain "Capture and Containment" Subparagraph below for assurance hood is operating as intended by design.

Capture and Containment: Check each hood for proper capture and containment using a smoke-emitting device. Observe and report performance. Make adjustments to achieve optimum results.

* + - * 1. AHJ Tests: Conduct additional tests required by authorities having jurisdiction.
			1. SOUND TESTS
				1. After systems are balanced and Substantial Completion, measure and record sound levels at [**five**] [**10**] [**15**] <**Insert number**> locations as designated by the Director’s Representative.
				2. Instrumentation:

The sound-testing meter shall be a portable, general-purpose testing meter consisting of a microphone, processing unit, and readout.

The sound-testing meter shall be capable of showing fluctuations at minimum and maximum levels, and measuring the equivalent continuous sound pressure level (Leq).

The sound-testing meter must be capable of using one-third octave band filters to measure mid-frequencies from 31.5 Hz to 8000 Hz.

The accuracy of the sound-testing meter shall be plus or minus one decibel.

* + - * 1. Test Procedures:

Perform test at quietest background noise period. Note cause of unpreventable sound that affects test outcome.

Equipment should be operating at design values.

Calibrate the sound-testing meter prior to taking measurements.

Use a microphone suitable for the type of noise levels measured that is compatible with meter. Provide a windshield for outside or in-duct measurements.

Record a set of background measurements in dBA and sound pressure levels in the eight unweighted octave bands [**63 Hz to 8000 Hz (NC)**] [**31.5 Hz to 4000 Hz (RC)**] with the equipment off.

Take sound readings in dBA and sound pressure levels in the eight unweighted octave bands [**63 Hz to 8000 Hz (NC)**] [**31.5 Hz to 4000 Hz (RC)**] with the equipment operating.

Take readings no closer than 36 inches36 inches (900 mm) from a wall or from the operating equipment and approximately 60 inches60 inches (1500 mm) from the floor, with the meter held or mounted on a tripod.

For outdoor measurements, move sound-testing meter slowly and scan area that has the most exposure to noise source being tested. Use A-weighted scale for this type of reading.

* + - * 1. Reporting:

Report shall record the following:

Location.

System tested.

dBA reading.

Sound pressure level in each octave band with equipment on and off.

Plot sound pressure levels on [**Noise Criteria (NC)**] [**or**] [**Room Criteria (RC)**] worksheet with equipment on and off.

* + - 1. VIBRATION TESTS
				1. After systems are balanced and Substantially Completion, measure and record vibration levels on equipment having motor horsepower equal to or greater than [**10**] [**15**] [**25**] <**Insert number**>.
				2. Instrumentation:

Use portable, battery-operated, and microprocessor-controlled vibration meter with or without a built-in printer.

The meter shall automatically identify engineering units, filter bandwidth, amplitude, and frequency scale values.

The meter shall be able to measure machine vibration displacement in mils of deflection, velocity in inches per second, and acceleration in inches per second squared.

Verify calibration date is current for vibration meter before taking readings.

* + - * 1. Test Procedures:

To ensure accurate readings, verify that accelerometer has a clean, flat surface and is mounted properly.

With the unit running, set up vibration meter in a safe, secure location. Connect transducer to meter with proper cables. Hold magnetic tip of transducer on top of the bearing, and measure unit in mils of deflection. Record measurement, then move transducer to the side of the bearing and record in mils of deflection. Record an axial reading in mils of deflection by holding nonmagnetic, pointed transducer tip on end of shaft.

Change vibration meter to velocity (inches per second) measurements. Repeat and record above measurements.

Record CPM or rpm.

Read each bearing on motor, fan, and pump as required. Track and record vibration levels from rotating component through casing to base.

* + - * 1. Reporting:

Report shall record location and the system tested.

Include horizontal-vertical-axial measurements for tests.

Verify that vibration limits follow Specifications, or, if not specified, follow the General Machinery Vibration Severity Chart or Vibration Acceleration General Severity Chart from AABC's "National Standards for Total System Balance." Acceptable levels of vibration are normally "smooth" to "good."

Include in General Machinery Vibration Severity Chart, with conditions plotted.

* + - 1. DUCT LEAKAGE TESTS
				1. Witness the duct leakage testing performed by Installer.
				2. Verify that proper test methods are used and that leakage rates are within specified limits.
				3. Report deficiencies observed.
			2. PIPE LEAKAGE TESTS
				1. Witness the pipe pressure testing performed by Installer.
				2. Verify that proper test methods are used and that leakage rates are within specified limits.
				3. Report deficiencies observed.
			3. UFAD PLENUM LEAKAGE TESTS

Coordinate requirements for UFAD plenum leakage performance and testing with other Sections. Retain this article if UFAD plenum testing is to be witnessed by TAB specialist for HVAC.

* + - * 1. Witness the UFAD plenum pressure testing performed by Installer.
				2. Verify that proper test methods are used and that leakage rates are within specified limits.
				3. Report deficiencies observed.
			1. HVAC CONTROLS VERIFICATION

Coordinate requirements of this article with Project commissioning, and edit requirements to avoid duplication.

* + - * 1. In conjunction with system balancing, perform the following:
				2. Verify HVAC control system is operating within the design limitations.
				3. Confirm that the sequences of operation are in compliance with Contract Documents.
				4. Verify that controllers are calibrated and function as intended.
				5. Verify that controller set points are as indicated.
				6. Verify the operation of lockout or interlock systems.
				7. Verify the operation of valve and damper actuators.
				8. Verify that controlled devices are properly installed and connected to correct controller.
				9. Verify that controlled devices travel freely and are in position indicated by controller: open, closed, or modulating.
				10. Verify location and installation of sensors to ensure that they sense only intended temperature, humidity, or pressure.
				11. Reporting: Include a summary of verifications performed, remaining deficiencies, and variations from indicated conditions.
			1. PROCEDURES FOR STAIR-PRESSURIZATION SYSTEMS

Stair-pressurization systems are designed to provide a means of egress during a fire or smoke event. The authority having jurisdiction is often the ultimate source of testing procedures and acceptance. This article is intended as a general procedure that should be revised to suit Project-specific requirements.

* + - * 1. Before testing, observe each pressurized stair enclosure to verify construction is complete. Verify the following:

Walls and ceiling are free of unintended openings and are capable of achieving a pressure boundary.

Firestopping and sealants are installed.

Doors, door closers, and door gaskets are installed and adjusted.

If applicable, window installation is complete.

Stair-pressurization fans and associated controls are installed and functioning properly.

Stair-pressurization duct distribution and air outlets are installed.

Life-safety dampers (smoke or combination fire and smoke) are installed and functioning properly.

* + - * 1. Measure and record barometric pressure, wind speed and direction, outdoor-air temperature, and relative humidity on each test day.
				2. Test each stair enclosure as a single system. If multiple fans serve a single stair enclosure, operate fans as intended by the design.
				3. Initial Air Balance:

Open doors to floors where indicated by design and measure, adjust, and record the airflow of each:

Stair-pressurization fan. For ducted systems, measure fan airflow by duct Pitot-tube traverse unless duct distribution does not permit accurate readings.

Air outlet supplying stair enclosure.

Adjust enclosure total airflow to achieve design pressurization.

Adjust method of stair enclosure pressure relief to prevent overpressurization.

* + - * 1. Pressurization Test and Adjustments:

After air balancing is complete, perform stair enclosure pressurization tests.

Establish a consistent procedure for recording data throughout entire test.

Use stair side of doors as pressure reference point.

Positive Pressure: Floor side of door higher than stair side.

Negative Pressure: Floor side of door lower than stair side.

With HVAC systems and stair-pressurization systems off, measure and record the following:

Pressure difference across each stair enclosure door, with all doors in the stair enclosure closed.

Force necessary to open each door, using a spring-type scale.

Adjustment needed to achieve design pressurization of enclosure total airflow.

Adjustment needed to method of stair enclosure pressure relief, to prevent overpressurization.

With HVAC systems operating in normal mode and stair-pressurization systems off, measure and record the following:

Pressure difference across each stair enclosure door, with all doors in the stair enclosure closed.

Force necessary to open each door, using a spring-type scale.

Adjustment needed to achieve design pressurization of enclosure total airflow.

Adjustment needed to method of stair enclosure pressure relief, to prevent overpressurization.

With HVAC systems and stair-pressurization system operating simultaneously, perform the following:

Place HVAC systems in normal operating mode, including equipment not used to implement smoke control, such as air-handling units, exhaust fans, and similar equipment.

Measure and record pressure difference across each stair enclosure door, with all doors in stair enclosure closed.

Use a spring scale to measure and record the force needed to open all stair enclosure doors.

Adjust enclosure total airflow to achieve design pressurization.

Adjust method of stair enclosure pressure relief to prevent overpressurization.

Retain "Additional Tests for Designs with Open Doors" Subparagraph below for special testing required by some governing codes and revise to suit Project.

Additional Tests for Designs with Open Doors:

With exit door to outdoors in open position, measure and record pressure difference across each of the remaining closed stair enclosure doors.

Open additional doors (up to the number indicated by design) one at a time, and measure and record pressure difference across each remaining closed stair enclosure door after the opening of each additional door.

For each different test condition, measure and record the direction and velocity through each of the open doors by a traverse of every [**1 sq. ft.1 sq. ft. (0.093 sq. m)**] <**Insert requirement**> grid of door opening.

For each different test condition, calculate average of door velocity measurements. Compare average velocity to design and governing code requirements.

Adjust enclosure total airflow to achieve design pressurization.

Adjust method of stair enclosure pressure relief to prevent overpressurization.

Repeat pressurization tests with the smoke-control systems and HVAC systems operating.

Criteria for Acceptance:

Compliance with design requirements.

Compliance with code requirements.

Compliance with additional requirements required by authorities having jurisdiction.

<**Insert other criteria**>.

Retain "Operational Tests" Paragraph below if tests indicated are to be performed as part of TAB for HVAC. Coordinate requirements with building commissioning and testing requirements of other Sections.

* + - * 1. Operational Tests:

Check proper activation of stair-pressurization system(s) in response to all means of activation, both automatic and manual.

Verify that each initiating occurrence produces the proper system response under each of the following modes of operation:

Normal.

Alarm.

Manual override.

Return to normal.

Verify smoke detector at pressurization fan de-energizes fan and closes isolation damper when smoke detector is activated and in alarm.

If standby power is provided for pressurization systems, test to verify pressurization systems operate while on both normal and standby power.

Check operation in accordance with design indicated.

* + - * 1. AHJ Tests: Conduct additional tests required by authorities having jurisdiction.
				2. Report: Prepare and submit a complete report of observations, measurements, and deficiencies. Include names and contact information of individuals conducting tests and of individuals witnessing tests.
			1. PROCEDURES FOR ELEVATOR-PRESSURIZATION SYSTEMS

Elevator-pressurization systems are designed to provide a means of egress during a fire or smoke event. The authority having jurisdiction is often the ultimate source of testing procedures and acceptance. This article is intended as a general procedure that should be revised to suit Project-specific requirements.

* + - * 1. Before testing, observe each pressurized elevator enclosure to verify construction is complete. Verify the following:

Walls and ceiling are free of unintended openings and are capable of achieving a pressure boundary.

Firestopping and sealants are installed.

Doors are installed and adjusted. Elevator car doors are recalled to the default recall floor, and elevator car doors on recall floor are open.

If applicable, window installation is complete.

Pressurization fans and associated controls are installed and functioning properly.

Pressurization duct distribution and air outlets are installed.

Life-safety dampers (smoke or combination fire and smoke) are installed and functioning properly.

* + - * 1. Measure and record barometric pressure, wind speed and direction, outdoor-air temperature, and relative humidity on each test day.
				2. Test each elevator enclosure as a single system. If multiple fans serve a single elevator enclosure, operate fans as intended by the design.
				3. Initial Air Balance:

Open elevator car doors to recall floor indicated by design, and measure, adjust, and record the airflow of each:

Pressurization fan. For ducted systems, measure fan airflow by duct pitot-tube traverse unless duct distribution does not permit accurate readings.

Air outlet supplying elevator enclosure.

Adjustment needed to achieve design pressurization of enclosure total airflow.

Adjustment to method of elevator enclosure pressure relief, to prevent overpressurization.

* + - * 1. Pressurization Tests and Adjustments:

After air balancing is complete, perform elevator enclosure pressurization tests.

Establish a consistent procedure for recording data throughout entire test.

Use elevator car side of doors as pressure reference point.

Positive Pressure: Floor side of door higher than elevator car side.

Negative Pressure: Floor side of door lower than elevator car side.

With HVAC systems and elevator-pressurization systems off, measure and record the following:

Pressure difference across each elevator enclosure door with all doors in the elevator enclosure closed.

Adjustment needed to achieve design pressurization of enclosure total airflow.

Adjustment needed to method of stair enclosure pressure relief, to prevent overpressurization.

With HVAC systems operating in normal mode and elevator pressurization systems off, measure and record the following:

Pressure difference across each elevator enclosure door with all doors in the elevator enclosure closed.

Adjustment needed to achieve design pressurization of enclosure total airflow.

Adjustment needed to method of stair enclosure pressure relief, to prevent overpressurization.

With HVAC systems and elevator pressurization system operating simultaneously, perform the following:

Place HVAC systems in normal operating mode, including equipment not used to implement smoke control, such as air-handling units, exhaust fans, and similar equipment.

Measure and record pressure difference across each stair enclosure door, with all doors in stair enclosure closed.

Adjust enclosure total airflow to achieve design pressurization.

Adjust method of elevator enclosure pressure relief to prevent overpressurization.

Repeat pressurization tests with smoke-control systems and HVAC systems operating.

Criteria for Acceptance:

Compliance with design requirements.

Compliance with code requirements.

Compliance with additional requirements of authorities having jurisdiction.

<**Insert other criteria**>.

Retain "Operational Tests" Paragraph below if tests indicated are to be performed as part of TAB for HVAC. Coordinate requirements with building commissioning and testing requirements of other Sections.

* + - * 1. Operational Tests:

Check proper activation of elevator-pressurization system(s) in response to all means of activation, both automatic and manual.

Verify that each initiating occurrence produces the proper system response under each of the following modes of operation:

Normal.

Alarm.

Manual override.

Return to normal.

Verify smoke detector at pressurization fan de-energizes fan and closes isolation damper when smoke detector is activated and in alarm.

If standby power is provided for pressurization systems, test to verify pressurization systems operate while on both normal and standby power.

Check operation according to design indicated.

* + - * 1. AHJ Tests: Conduct additional tests required by authorities having jurisdiction.
				2. Report: Prepare and submit a complete report of observations, measurements, and deficiencies. Include names and contact information of individuals conducting tests and of individuals witnessing tests.
			1. PROCEDURES FOR SMOKE-CONTROL SYSTEM TESTING

Smoke-control systems are designed to provide a means of egress during a fire or smoke event. The authority having jurisdiction is often the ultimate source of testing procedures and acceptance. This article is intended as a general procedure that should be revised to suit Project-specific requirements.

* + - * 1. Before testing smoke-control systems, review design documents to understand operating requirements and design intent:

Review boundaries of each smoke zone.

Review location, size, and operating characteristics of equipment, such as smoke and fire smoke dampers.

Review sequence of operation, operating status of equipment, and position of smoke and fire dampers for each smoke zone alarm condition.

Review location and type of alarm detection used to initiate smoke control for each smoke zone.

Review other smoke-control system attributes not listed but required for code compliance and acceptance by authorities having jurisdiction.

* + - * 1. Before testing smoke-control systems, verify that construction is complete and verify the integrity of each smoke-control zone boundary.

Verify that windows, doors, walls, ceilings, and floors (six-sided boundary) are closed and that applicable safing, gasket, and firestops and sealants are installed.

Report deficiencies and postpone testing until after the reported deficiencies are corrected.

* + - * 1. Measure and record barometric pressure, wind speed and direction, outdoor-air temperature, and relative humidity on each test day.
				2. Measure, adjust, and record airflow of each smoke-control system, with all fans that are a part of system operating as intended by the design.

Measure, adjust, and record the airflow of each fan. For ducted systems, measure fan airflow by duct Pitot-tube traverse.

Measure, adjust, and record the airflow of each exhaust inlet and supply outlet.

Measure, adjust, and record airflow in main and branch ducts.

Retain "Smoke Control by Pressurization" Paragraph below for systems that are designed to maintain a pressure across smoke zone boundaries.

* + - * 1. Smoke Control by Pressurization: After air balancing is complete, perform the following pressurization testing for each smoke-control zone in the system designed for isolation by using pressurization boundaries:

Verify the boundaries of each smoke-control zone.

With the HVAC systems in their normal mode of operation and smoke control not operating, measure and record the pressure difference across each smoke-control zone. Make measurements after closing doors that separate the zones. Make one measurement across each door. Clearly indicate the high- and low-pressure side of each door.

With the system operating in the smoke-control mode and with each separate zone in the smoke-control system activated, perform the following:

Measure and record the pressure difference across each door that separates the smoke zone from adjacent zones.

Make measurements with doors that separate the smoke zone from the other zones closed.

Clearly indicate the high- and low-pressure side of the door.

Doors that have a tendency to open slightly due to the pressure difference should have one pressure measurement made while held closed and another measurement made with the door open.

Continue to activate each separate smoke zone within each smoke-control system, and make pressure-difference measurements.

After testing a smoke zone's smoke-control system, deactivate the HVAC systems involved and return them to their normal operating mode before activating another zone's smoke-control system.

Verify that controls necessary to prevent excessive pressure differences are functional and operating within design set points and limits.

Retain "Smoke-Control Systems for Atriums and Other Large-Volume Spaces" Paragraph below for smoke-control systems designed to serve atriums and other large-volume spaces.

* + - * 1. Smoke-Control Systems for Atriums and Other Large-Volume Spaces: After air balancing is complete, perform the following testing for each smoke-control system serving atriums and other large-volume spaces:

Verify and document the boundaries served by each smoke-control system.

Identify and document closed doors, open doors, and other boundary openings to be left open to adjacent areas and that are to be protected by airflow alone.

With the HVAC systems in their normal mode of operation and smoke-control systems not operating, measure and record the following:

Pressure difference across each door that separates the smoke-zone from adjacent zones.

Velocity for each point in traverse across each boundary opening:

Clearly indicate the direction of flow.

Measure velocity across opening on [**12-inch12-inch (300-mm)**] <**Insert dimension**> centers using a vane anemometer.

Calculate and report airflow.

With system operating in the smoke-control mode, measure and record the following:

Pressure difference across each door that separates the smoke-zone from adjacent zones.

Velocity for each point in traverse across each opening:

Clearly indicate the direction of flow.

Measure velocity across opening on [**12-inch12-inch (300-mm)**] <**Insert dimension**> centers using a vane anemometer.

Calculate and report airflow.

Verify system operation and make adjustments to achieve design pressure differences and air velocities within design set points and upper operating limits.

Retain "Operational Tests" Paragraph below if tests indicated are to be performed as part of TAB for HVAC. Coordinate requirements with building commissioning and testing requirements of other Sections.

* + - * 1. Operational Tests:

Check the proper activation of each zone of each smoke-control system in response to all means of activation, both automatic and manual.

Check automatic activation in response to fire alarm signals received from the building's fire alarm system. Initiate a separate alarm for each means of activation to ensure that the proper operation of the correct zone of each smoke-control system occurs.

Check and record proper operation of fans, dampers, and related equipment for each separate zone of each smoke-control system:

Zone in which a smoke-control system automatically activates.

Type of signal that activates smoke-control system, such as sprinkler flow or smoke detector.

Smoke zone(s) where maximum mechanical exhaust to the outside is implemented and no supply air is provided.

Positive-pressure smoke-control zone(s) where maximum air supply is implemented and no exhaust to the outside is provided.

Fan(s) "ON" as required to implement the smoke-control system. Multiple- or variable-speed fans should be further noted to verify that the intended control configuration is achieved.

Fan(s) "OFF" as required to implement the smoke-control system.

Damper(s) "OPEN" or at an adjustable position where maximum airflow must be achieved.

Damper(s) "CLOSED" where no airflow should take place.

Auxiliary functions to achieve the smoke-control system configuration, such as changes or override of normal operating pressure and temperature-control set points.

If standby power is provided for the smoke-control system, test to verify that the system functions while operating under both normal and standby power.

Check operation in accordance with design indicated.

* + - * 1. AHJ Tests: Conduct additional tests required by authorities having jurisdiction. [**Unless required by authorities having jurisdiction, perform testing without the use of smoke or products that simulate smoke.**]
				2. Report: Prepare and submit a complete report of observations, measurements, and deficiencies. Include names and contact information of individuals conducting tests and of individuals witnessing tests.
			1. PROCEDURES FOR TESTING, ADJUSTING, AND BALANCING EXISTING SYSTEMS
				1. Perform a preconstruction inspection of existing equipment that is to remain and be reused.

Measure and record the operating speed, airflow, and static pressure of each fan and equipment with fan(s).

Measure and record flows, temperatures, and pressures of each piece of equipment in each hydronic system. Compare the values to design or nameplate information, where information is available.

Measure motor voltage and amperage. Compare the values to motor nameplate information.

Check the refrigerant charge.

Check the condition of filters.

Check the condition of coils.

Check the operation of the drain pan and condensate-drain trap.

Check bearings and other lubricated parts for proper lubrication.

Report on the operating condition of the equipment and the results of the measurements taken. Report deficiencies.

* + - * 1. TAB After Construction: Before performing testing and balancing of renovated existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished in accordance with renovation scope indicated by Contract Documents. Verify the following:

New filters are installed.

Coils are clean and fins combed.

Drain pans are clean.

Fans are clean.

Bearings and other parts are properly lubricated.

Deficiencies noted in the preconstruction report are corrected.

* + - * 1. Perform testing and balancing of existing systems to the extent that existing systems are affected by the renovation work.

Compare the indicated airflow of the renovated work to the measured fan airflows, and determine the new fan speed and the face velocity of filters and coils.

Verify that the indicated airflows of the renovated work result in filter and coil face velocities and fan speeds that are within the acceptable limits defined by equipment manufacturer.

If calculations increase or decrease the airflow rates and water flow rates by more than [**5**] <**Insert number**> percent, make equipment adjustments to achieve the calculated rates. If increase or decrease is [**5**] <**Insert number**> percent or less, equipment adjustments are not required.

Balance each air outlet.

* + - 1. TOLERANCES
				1. Set HVAC system's airflow rates and water flow rates within the following tolerances:

Supply, Return, and Exhaust Fans and Equipment with Fans: [**Plus or minus 10 percent**] [**Plus 10 percent or minus 5 percent**] <**Insert value**>. If design value is less than 100 cfm100 cfm (47 L/s), within 10 cfm10 cfm (4.7 L/s).

Air Outlets and Inlets: [**Plus or minus 10 percent**] [**Plus 10 percent or minus 5 percent**] <**Insert value**>. If design value is less than 100 cfm100 cfm (47 L/s), within 10 cfm10 cfm (4.7 L/s).

Heating-Water Flow Rate: [**Plus or minus 5 percent**] [**Plus or minus 10 percent**] [**Plus 10 percent or minus 5 percent**] <**Insert value**>. If design value is less than 10 gpm10 gpm (0.63 L/s), within 10 percent.

Chilled-Water Flow Rate: [**Plus or minus 5 percent**] [**Plus or minus 10 percent**] [**Plus 10 percent or minus 5 percent**] <**Insert value**>. If design value is less than 10 gpm10 gpm (0.63 L/s), within 10 percent.

Condenser-Water Flow Rate: [**Plus or minus 5 percent**] [**Plus or minus 10 percent**] [**Plus 10 percent or minus 5 percent**] <**Insert value**>.

* + - * 1. Maintaining pressure relationships as designed shall have priority over the tolerances specified above.
			1. PROGRESS REPORTING
				1. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for system-balancing devices. Recommend changes and additions to system-balancing devices, to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance-measuring and -balancing devices.
				2. Status Reports: Prepare [**weekly**] [**biweekly**] [**monthly**] <**Insert time interval**> progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.
			2. FINAL REPORT

Revise contents of reports specified in this article to suit office practice.

* + - * 1. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.

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

Certify validity and accuracy of field data.

* + - * 1. Final Report Contents: In addition to certified field-report data, include the following:

Pump curves.

Fan curves.

Manufacturers' test data.

Field test reports prepared by system and equipment installers.

Other information relative to equipment performance; do not include Shop Drawings and Product Data.

* + - * 1. General Report Data: In addition to form titles and entries, include the following data:

Title page.

Name and address of the TAB specialist.

Project name.

Project location.

Architect's name and address.

Engineer's Director’s Representative name and address.

Contractor's name and address.

Report date.

Signature of TAB supervisor who certifies the report.

Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.

Summary of contents, including the following:

Indicated versus final performance.

Notable characteristics of systems.

Description of system operation sequence if it varies from the Contract Documents.

Nomenclature sheets for each item of equipment.

Data for terminal units, including manufacturer's name, type, size, and fittings.

Notes to explain why certain final data in the body of reports vary from indicated values.

Test conditions for fans performance forms, including the following:

Settings for outdoor-, return-, and exhaust-air dampers.

Conditions of filters.

Cooling coil, wet- and dry-bulb conditions.

Heating coil, dry-bulb conditions.

Face and bypass damper settings at coils.

Fan drive settings, including settings and percentage of maximum pitch diameter.

[**Variable-frequency controller**] [**Inlet vane**] settings for variable-air-volume systems.

Settings for pressure controller(s).

Other system operating conditions that affect performance.

Test conditions for pump performance forms, including the following:

Variable-frequency controller settings for variable-flow hydronic systems.

Settings for pressure controller(s).

Other system operating conditions that affect performance.

* + - * 1. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:

Quantities of outdoor, supply, return, and exhaust airflows.

Water and steam flow rates.

Duct, outlet, and inlet sizes.

Pipe and valve sizes and locations.

Terminal units.

Balancing stations.

Position of balancing devices.

* + - * 1. Air-Handling-Unit Test Reports: For air-handling units, include the following:

Unit Data:

Unit identification.

Location.

Make and type.

Model number and unit size.

Manufacturer's serial number.

Unit arrangement and class.

Discharge arrangement.

Sheave make, size in inches (mm), and bore.

Center-to-center dimensions of sheave and amount of adjustments in inches (mm).

Number, make, and size of belts.

Number, type, and size of filters.

Motor Data:

Motor make, and frame type and size.

Horsepower and speed.

Volts, phase, and hertz.

Full-load amperage and service factor.

Sheave make, size in inches (mm), and bore.

Center-to-center dimensions of sheave and amount of adjustments in inches (mm).

Test Data (Indicated and Actual Values):

Total airflow rate in cfm (L/s).

Total system static pressure in inches wg (Pa).

Fan speed.

Inlet and discharge static pressure in inches wg (Pa).

For each filter bank, filter static-pressure differential in inches wg (Pa).

Preheat-coil static-pressure differential in inches wg (Pa).

Cooling-coil static-pressure differential in inches wg (Pa).

Heating-coil static-pressure differential in inches wg (Pa).

List for each internal component with pressure-drop, static-pressure differential in inches wg (Pa).

Outdoor airflow in cfm (L/s).

Return airflow in cfm (L/s).

Outdoor-air damper position.

Return-air damper position.

[**Vortex damper position**].

* + - * 1. Apparatus-Coil Test Reports:

Coil Data:

System identification.

Location.

Coil type.

Number of rows.

Fin spacing in fins per inch fins per inch (mm) o.c.

Make and model number.

Face area in sq. ft.sq. ft. (sq. m).

Tube size in NPSNPS (DN).

Tube and fin materials.

Circuiting arrangement.

Test Data (Indicated and Actual Values):

Airflow rate in cfm (L/s).

Average face velocity in fpm (m/s).

Air pressure drop in inches wg (Pa).

Outdoor-air, wet- and dry-bulb temperatures in deg F (deg C).

Return-air, wet- and dry-bulb temperatures in deg F (deg C).

Entering-air, wet- and dry-bulb temperatures in deg F (deg C).

Leaving-air, wet- and dry-bulb temperatures in deg F (deg C).

Retain first four subparagraphs below for hydronic coils.

Water flow rate in gpm (L/s).

Water pressure differential in feet of head or psig feet of head or psig (kPa).

Entering-water temperature in deg F (deg C).

Leaving-water temperature in deg F (deg C).

Retain first three subparagraphs below for refrigerant coils.

Refrigerant expansion valve and refrigerant types.

Refrigerant suction pressure in psig (kPa).

Refrigerant suction temperature in deg F (deg C).

Retain subparagraph below for steam coil.

Inlet steam pressure in psig (kPa).

* + - * 1. Gas- and Oil-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:

Unit Data:

System identification.

Location.

Make and type.

Model number and unit size.

Manufacturer's serial number.

Fuel type in input data.

Output capacity in Btu/h (kW).

Ignition type.

Burner-control types.

Motor horsepower and speed.

Motor volts, phase, and hertz.

Motor full-load amperage and service factor.

Sheave make, size in inches (mm), and bore.

Center-to-center dimensions of sheave and amount of adjustments in inches (mm).

Test Data (Indicated and Actual Values):

Total airflow rate in cfm (L/s).

Entering-air temperature in deg F (deg C).

Leaving-air temperature in deg F (deg C).

Air temperature differential in deg F (deg C).

Entering-air static pressure in inches wg (Pa).

Leaving-air static pressure in inches wg (Pa).

Air static-pressure differential in inches wg (Pa).

Low-fire fuel input in Btu/h (kW).

High-fire fuel input in Btu/h (kW).

Manifold pressure in psig (kPa).

High-temperature-limit setting in deg F (deg C).

Operating set point in Btu/h (kW).

Motor voltage at each connection.

Motor amperage for each phase.

Heating value of fuel in Btu/h (kW).

* + - * 1. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air-handling units, include the following:

Unit Data:

System identification.

Location.

Coil identification.

Capacity in Btu/h (kW).

Number of stages.

Connected volts, phase, and hertz.

Rated amperage.

Airflow rate in cfm (L/s).

Face area in sq. ft.sq. ft. (sq. m).

Minimum face velocity in fpm (m/s).

Test Data (Indicated and Actual Values):

Heat output in Btu/h (kW).

Airflow rate in cfm (L/s).

Air velocity in fpm (m/s).

Entering-air temperature in deg F (deg C).

Leaving-air temperature in deg F (deg C).

Voltage at each connection.

Amperage for each phase.

* + - * 1. Fan Test Reports: For supply, return, and exhaust fans, include the following:

Fan Data:

System identification.

Location.

Make and type.

Model number and size.

Manufacturer's serial number.

Arrangement and class.

Sheave make, size in inches (mm), and bore.

Center-to-center dimensions of sheave and amount of adjustments in inches (mm).

Motor Data:

Motor make, and frame type and size.

Horsepower and speed.

Volts, phase, and hertz.

Full-load amperage and service factor.

Sheave make, size in inches (mm), and bore.

Center-to-center dimensions of sheave and amount of adjustments in inches (mm).

Number, make, and size of belts.

Test Data (Indicated and Actual Values):

Total airflow rate in cfm (L/s).

Total system static pressure in inches wg (Pa).

Fan speed.

Discharge static pressure in inches wg (Pa).

Suction static pressure in inches wg (Pa).

* + - * 1. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

Report Data:

System fan and air-handling-unit number.

Location and zone.

Traverse air temperature in deg F (deg C).

Duct static pressure in inches wg (Pa).

Duct size in inches (mm).

Duct area in sq. ft.sq. ft. (sq. m).

Indicated airflow rate in cfm (L/s).

Indicated velocity in fpm (m/s).

Actual airflow rate in cfm (L/s).

Actual average velocity in fpm (m/s).

Barometric pressure in psig (Pa).

* + - * 1. Air-Terminal-Device Reports:

Unit Data:

System and air-handling unit identification.

Location and zone.

Apparatus used for test.

Area served.

Make.

Number from system diagram.

Type and model number.

Size.

Effective area in sq. ft.sq. ft. (sq. m).

Test Data (Indicated and Actual Values):

Airflow rate in cfm (L/s).

Air velocity in fpm (m/s).

Preliminary airflow rate as needed in cfm (L/s).

Preliminary velocity as needed in fpm (m/s).

Final airflow rate in cfm (L/s).

Final velocity in fpm (m/s).

Space temperature in deg F (deg C).

* + - * 1. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

Unit Data:

System and air-handling-unit identification.

Location and zone.

Room or riser served.

Coil make and size.

Flowmeter type.

Test Data (Indicated and Actual Values):

Airflow rate in cfm (L/s).

Entering-water temperature in deg F (deg C).

Leaving-water temperature in deg F (deg C).

Water pressure drop in feet of head or psig feet of head or psig (kPa).

Entering-air temperature in deg F (deg C).

Leaving-air temperature in deg F (deg C).

Net positive suction head is important for pumps in open circuits and for pumps handling fluids at elevated temperatures.

* + - * 1. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves, and include the following:

Unit Data:

Unit identification.

Location.

Service.

Make and size.

Model number and serial number.

Water flow rate in gpm (L/s).

Water pressure differential in feet of head or psig feet of head or psig (kPa).

Required net positive suction head in feet of head or psig feet of head or psig (kPa).

Pump speed.

Impeller diameter in inches (mm).

Motor make and frame size.

Motor horsepower and rpm.

Voltage at each connection.

Amperage for each phase.

Full-load amperage and service factor.

Seal type.

Test Data (Indicated and Actual Values):

Static head in feet of head or psig feet of head or psig (kPa).

Pump shutoff pressure in feet of head or psig feet of head or psig (kPa).

Actual impeller size in inches (mm).

Full-open flow rate in gpm (L/s).

Full-open pressure in feet of head or psig feet of head or psig (kPa).

Final discharge pressure in feet of head or psig feet of head or psig (kPa).

Final suction pressure in feet of head or psig feet of head or psig (kPa).

Final total pressure in feet of head or psig feet of head or psig (kPa).

Final water flow rate in gpm (L/s).

Voltage at each connection.

Amperage for each phase.

* + - * 1. Instrument Calibration Reports:

Report Data:

Instrument type and make.

Serial number.

Application.

Dates of use.

Dates of calibration.

* + - 1. VERIFICATION OF TAB REPORT
				1. The TAB specialist's test and balance engineer shall conduct the inspection in the presence of [**Director’s Representative**] [**Owner**] [**Construction Manager**] [**Commissioning Authority**].
				2. [**Director’s Representative**] [**Owner**] [**Construction Manager**] [**Commissioning Authority**] shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to the lesser of either [**10**] <**Insert number**> percent of the total measurements recorded or the extent of measurements that can be accomplished in [**a normal 8-hour business day**] <**Insert value**>.
				3. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
				4. If the number of "FAILED" measurements is greater than [**10**] [**20**] <**Insert number**> percent of the total measurements checked during the final inspection, the TAB shall be considered incomplete and shall be rejected.

See Section 014000 "Quality Requirements" for retesting and reinspecting requirements and Section 017300 "Execution" for requirements for correcting the Work.

* + - * 1. If recheck measurements find the number of failed measurements noncompliant with requirements indicated, proceed as follows:

TAB specialists shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection. All changes shall be tracked to show changes made to previous report.

If the second final inspection also fails, Director’s Representative may pursue others Contract options to complete TAB work.

* + - * 1. Prepare test and inspection reports.
			1. ADDITIONAL TESTS
				1. Within [**90**] <**Insert number**> days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.
				2. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.
				3. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

END OF SECTION 230593