DESCRIPTION.
This work shall consist of testing, adjusting and balancing work for all heating, ventilation and air-conditioning systems to complete the renovation of the facilities in accordance with the Contract Drawings, specifications and/or as ordered by the Engineer.

The Contractor shall include TAB to produce design objectives for the following:

Air Systems: Constant-volume air systems.

Vibration measuring.

Sound level measuring.

Verifying that automatic control devices are functioning properly.

Reporting results of activities and procedures specified in this Section.

DEFINITIONS:
Adjust: To regulate fluid flow rate and air patterns at the terminal equipment, such as to reduce fan speed or adjust a damper.

Balance: To proportion flows within the distribution system, including submains, branches, and terminals, according to indicated quantities.

Barrier or Boundary: Construction, either vertical or horizontal, such as walls, floors, and ceilings that are designed and constructed to restrict the movement of airflow, smoke, odors, and other pollutants.

Draft: A current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person's skin than is normally dissipated.

NC: Noise criteria.

Procedure: An approach to and execution of a sequence of work operations to yield repeatable results.

RC: Room criteria.

Report Forms: Test data sheets for recording test data in logical order.

TAB: Testing, adjusting, and balancing.

Terminal: A point where the controlled medium, such as fluid or energy, enters or leaves the distribution system.

Test: A procedure to determine quantitative performance of systems or equipment.
Testing, Adjusting, and Balancing (TAB) Firm: The entity responsible for performing and reporting TAB procedures.

**MATERIALS.**
The Contractor shall provide the following submittals:

Qualification Data: Within 45 days from Contractor's Notice to Proceed, submit 6 copies of evidence that TAB firm and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.

Contract Documents Examination Report: Within 15 days from Contractor's Notice to Proceed, submit 6 copies of the Contract Documents review report as specified in construction details.

Strategies and Procedures Plan: Within 60 days from Contractor's Notice to Proceed, submit 6 copies of TAB strategies and step-by-step procedures. Include a complete set of report forms intended for use on this Project.

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

Sample Report Forms: Submit two sets of sample TAB report forms.

Warranties specified in this Section.

The Contractor shall engage a TAB firm certified by AABC. (The Association of Air Balance Council).

**CONSTRUCTION DETAILS.**
TAB Contractor shall provide the following examination:

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.

Contract Documents are defined in the General and Supplementary Conditions of Contract.

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

Examine approved submittal data of HVAC systems and equipment.

Examine Project Record Documents.

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.
Examine equipment performance data including fan curves. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system. Calculate system effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," Sections 7 through 10; or in Sheet Metal and Air Conditioning Contractor National Association, Inc. (SMACNA's) "HVAC Systems--Duct Design," Sections 5 and 6. Compare this data with the design data and installed conditions.

Examine system and equipment installations to verify that they are complete and that testing, cleaning, adjusting, and commissioning specified in individual Items have been performed.

Examine system and equipment test reports.

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

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

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

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

Examine automatic temperature system components to verify the following:

Dampers, valves, and other controlled devices are operated by the intended controller. Dampers and valves are in the position indicated by the controller.

Integrity of valves and dampers for free and full operation and for tightness of fully closed and fully open positions. This includes dampers in mixing boxes.

Thermostats are located to avoid adverse effects of sunlight, drafts, and cold walls.

Sensors are located to sense only the intended conditions.

Sequence of operation for control modes is according to the Contract Documents.

Controller set points are set at indicated values.

Interlocked systems are operating.

Changeover from heating to cooling mode occurs according to indicated values.
ITEM 11631.1105 M - TESTING, ADJUSTING, AND BALANCING (TAB)

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.

PREPARATION PROCEDURES:

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

Complete system readiness checks and prepare system readiness reports. Verify the following:

Permanent electrical power wiring is complete.

Automatic temperature-control systems are operational.

Equipment and duct access doors are securely closed.

Balance dampers are open.

Isolating and balancing valves are open and control valves are operational.

Windows and doors can be closed so indicated conditions for system operations can be met.

GENERAL PROCEDURES FOR TESTING AND BALANCING

Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems" SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing" and this Item.

Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed.

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

Take and report testing and balancing measurements in metric (SI) units.

GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

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.

Prepare schematic diagrams of systems' "as-built" duct layouts.

Determine the best locations in main and branch ducts for accurate duct airflow measurements.
Check airflow patterns from the outside-air louvers and dampers and the return- and exhaust-air dampers, through the supply-fan discharge and mixing dampers.

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

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

Check dampers for proper position to achieve desired airflow path.

Check for airflow blockages.

Check condensate drains for proper connections and functioning.

Check for proper sealing of air-handling unit components.

Check for proper sealing of air duct system.

PROCEDURES FOR MOTORS

Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:

Manufacturer, model, and serial numbers.

Motor horsepower rating.

Motor rpm.

Efficiency rating.

Nameplate and measured voltage, each phase.

Nameplate and measured amperage, each phase.

Starter thermal-protection-element rating.

PROCEDURES FOR HEAT-TRANSFER COILS

Electric-Heating Coils: Measure the following data for each coil:

Nameplate data.

Airflow.

Entering-and leaving-air temperature at full load.
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Voltage and amperage input of each phase at full load and at each incremental stage.

Calculated kilowatt at full load.

Fuse or circuit-breaker rating for overload protection.

Refrigerant Coils: Measure the following data for each coil:

Dry-bulb temperature of entering and leaving air.

Wet-bulb temperature of entering and leaving air.

Airflow.

Air pressure drop.
Refrigerant suction pressure and temperature.

PROCEDURES FOR TEMPERATURE MEASUREMENTS

During TAB, report the need for adjustment in temperature regulation within the automatic temperature-control system.

Measure indoor wet- and dry-bulb temperatures every other hour for a period of two successive eight-hour days, in each separately controlled zone, to prove correctness of final temperature settings. Measure when the building or zone is occupied.

Measure outside-air, wet- and dry-bulb temperatures.

PROCEDURES FOR VIBRATION MEASUREMENTS

Use a vibration meter meeting the following criteria:

Solid-state circuitry with a piezoelectric accelerometer.

Velocity range of 2.5 to 254 mm/s.

Displacement range of 0.0254 to 2.54 mm.

Frequency range of at least 0 to 1000 Hz.

Capable of filtering unwanted frequencies.

Calibrate the vibration meter before each day of testing.

Use a calibrator provided with the vibration meter.
Follow vibration meter and calibrator manufacturer's calibration procedures.

Perform vibration measurements when other building and outdoor vibration sources are at a minimum level and will not influence measurements of equipment being tested.

Turn off equipment in the building that might interfere with testing.

Clear the space of people.

Perform vibration measurements after air and water balancing and equipment testing is complete. Clean equipment surfaces in contact with the vibration transducer.

Position the vibration transducer according to manufacturer's written instructions and to avoid interference with the operation of the equipment being tested.

Measure and record vibration on rotating equipment over 2.2 kW.

Measure and record equipment vibration, bearing vibration, equipment base vibration, and building structure vibration. Record velocity and displacement readings in the horizontal, vertical, and axial planes.

Fans and HVAC Equipment with Fans:

Fan Bearing: Drive end and opposite end.

Motor Bearing: Drive end and opposite end.

Equipment Casing: Top and side.

Equipment Base: Top and side.

Building: Floor.

Ductwork: To and from equipment after flexible connections.

Piping: To and from equipment after flexible connections.

For equipment with vibration isolation, take floor measurements with the vibration isolation blocked solid to the floor and with the vibration isolation floating. Calculate and report the differences.

Inspect, measure, and record vibration isolation.

Verify that vibration isolation is installed in the required locations.

Verify that installation is level and plumb.

Verify that isolators are properly anchored.
For spring isolators, measure the compressed spring height, the spring OD, and the travel-to-solid distance.

Measure the operating clearance between each inertia base and the floor or concrete base below. Verify that there is unobstructed clearance between the bottom of the inertia base and the floor.

PROCEDURES FOR SOUND-LEVEL MEASUREMENTS

Perform sound-pressure-level measurements with an octave-band analyzer complying with ANSI S1.4 for Type 1 sound-level meters and ANSI S1.11 for octave-band filters. Comply with requirements in ANSI S1.13, unless otherwise indicated.

Calibrate sound meters before each day of testing. Use a calibrator provided with the sound meter complying with ANSI S1.40 and that has NIST certification.

Use a microphone that is suitable for the type of sound levels measured. For areas where air velocities exceed 0.51 m/s, use a windscreen on the microphone.

Perform sound-level testing after air and water balancing and equipment testing are complete.

Close windows and doors to the space.

Perform measurements when the space is not occupied and when the occupant noise level from other spaces in the building and outside are at a minimum.

Clear the space of temporary sound sources so unrelated disturbances will not be measured. Position testing personnel during measurements to achieve a direct line-of-sight between the sound source and the sound-level meter.

Take sound measurements at a height approximately 1200 mm above the floor and at least 900 mm from a wall, column, and other large surface capable of altering the measurements.

Take sound measurements in dBA and in each of the 8 unweighted octave bands in the frequency range of 63 to 8000 Hz.

Take sound measurements with the HVAC systems off to establish the background sound levels and take sound measurements with the HVAC systems operating.

Calculate the difference between measurements. Apply a correction factor depending on the difference and adjust measurements.

Perform sound testing at one location on Project for each of the following space types. For each space type tested, select a measurement location that has the greatest sound level. If testing multiple locations for each space type, select at least one location that is near and at least one location that is remote from the predominant sound source.

Lunch room where AHU is installed.
TEMPERATURE-CONTROL VERIFICATION

Verify that controllers are calibrated and commissioned.

Check transmitter and controller locations and note conditions that would adversely affect control functions.

Record controller settings and note variances between set points and actual measurements.

Check the operation of limiting controllers (i.e., high- and low-temperature controllers).

Check free travel and proper operation of control devices such as damper and valve operators.

Check the sequence of operation of control devices. Note air pressures and device positions and correlate with airflow and water flow measurements. Note the speed of response to input changes.

Check the interaction of electrically operated switch transducers.

Check the interaction of interlock and lockout systems.

Check main control supply-air pressure and observe compressor and dryer operations.

Record voltages of power supply and controller output. Determine whether the system operates on a grounded or nongrounded power supply.

Note operation of electric actuators using spring return for proper fail-safe operations.

TOLERANCES

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

Supply, Return, and Exhaust Fans and Equipment with Fans: Plus 5 to plus 10 percent.

Air Outlets and Inlets: 0 to minus 10 percent.

REPORTING

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 systems' balancing devices. Recommend changes and additions to systems' 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.

Status Reports: As Work progresses, prepare 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.

FINAL REPORT

General: Typewritten, or computer printout in letter-quality font, on standard bond paper, in three-ring binder, tabulated and divided into sections by tested and balanced systems, and on CD in word document or acrobat reader format in addition to printed coy.

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

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

Final Report Contents: In addition to certified field report data, include the following:

Fan curves.

Manufacturers' test data.

Field test reports prepared by system and equipment installers.

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

GENERAL REPORT DATA: In addition to form titles and entries, include the following data in the final report, as applicable:

Title page.

Name and address of TAB firm.

Project name.

Project location.

Architect's name and address.

Engineer's name and address.

Contractor's name and address.

Report date.

Signature of TAB firm 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.
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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, type size, and fittings.

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

Test conditions for fans performance forms including the following:

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

Conditions of filters.

Cooling coil, wet- and dry-bulb conditions.

Face and bypass damper settings at coils.

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

Inlet vane settings for variable-air-volume systems.

Settings for supply-air, static-pressure controller.

Other system operating conditions that affect performance.

AIR-HANDLING UNIT TEST REPORTS: For air-handling units with coils, include the following:

Unit Data: Include the following:

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 mm, and bore.

Sheave dimensions, center-to-center, and amount of adjustments in mm.

Number of belts, make, and size.

Number of filters, type, and size.

Motor Data:

Make and frame type and size.
Horsepower and rpm.
Volts, phase, and hertz.
Full-load amperage and service factor.
Sheave make, size in mm, and bore.
Sheave dimensions, center-to-center, and amount of adjustments in mm.

Test Data (Indicated and Actual Values):
Total airflow rate in m$^3$/sec.
Total system static pressure in Pa.
Fan rpm.
Discharge static pressure in Pa.
Filter static-pressure differential in Pa.
Preheat coil static-pressure differential in Pa.
Cooling coil static-pressure differential in Pa.
Heating coil static-pressure differential in Pa.
Outside airflow in m$^3$/sec.
Return airflow in m$^3$/sec.
Outside-air damper position.
Return-air damper position.
Vortex damper position.

ELECTRIC-COIL TEST REPORTS: For electric coils installed in central-station air-handling units, include the following:

Unit Data:

System identification.
Location.
Coil identification.
Capacity in kW.
Number of stages.
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Connected volts, phase, and hertz.

Rated amperage.
Airflow rate in m³/sec.
Face area in sq. m.
Minimum face velocity in m/s.

Test Data (Indicated and Actual Values):
Heat output in kW.
Airflow rate in m³/sec.
Air velocity in m/s.
Entering-air temperature in deg C.
Leaving-air temperature in deg C.
Voltage at each connection.
Amperage for each phase.

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 mm, and bore.
Sheave dimensions, center-to-center, and amount of adjustments in mm.

Motor Data:
Make and frame type and size.
Horsepower and rpm.
Volts, phase, and hertz.
Full-load amperage and service factor.
Sheave make, size in mm, and bore.
Sheave dimensions, center-to-center, and amount of adjustments in mm.
Number of belts, make, and size.

Test Data (Indicated and Actual Values):
Total airflow rate in m³/sec.
Total system static pressure in Pa.
Fan rpm.
Discharge static pressure in Pa.
Suction static pressure in Pa.
RECTANGULAR DUCT TRAVERSE REPORTS: Include a diagram with a grid representing the duct cross-section and record the following:

Report Data:

System and air-handling unit number.
Location and zone.
Traverse air temperature in deg C.
Duct static pressure in Pa.
Duct size in mm.
Duct area in sq. m.
Indicated airflow rate in m³/sec.
Indicated velocity in m/s.
Actual airflow rate in m³/sec.
Actual average velocity in m/s.
Barometric pressure in Pa.

Air-Terminal-Device Reports:

Unit Data:

System and air-handling unit identification.
Location and zone.
Test apparatus used.
Area served.
Air-terminal-device make.
Air-terminal-device number from system diagram.
Air-terminal-device type and model number.
Air-terminal-device size.
Air-terminal-device effective area in sq. m.
Test Data (Indicated and Actual Values):
Airflow rate in m³/sec.
Air velocity in m/s.
Preliminary airflow rate as needed in m³/sec.
Preliminary velocity as needed in m/s.
Final airflow rate in m³/sec.
Final velocity in m/s.
Space temperature in deg C.

COMPRESSOR REPORTS: For refrigerant side of unitary systems, stand-alone refrigerant compressors, include the following:

Unit Data:

Unit identification.
Location.
Unit make and model number.
Compressor make.
Compressor model and serial numbers.
Refrigerant weight in kg.
Low ambient temperature cutoff in deg C.

Test Data (Indicated and Actual Values):

Inlet-duct static pressure in Pa.
Outlet-duct static pressure in Pa.
Entering-air, dry-bulb temperature in deg C.
Leaving-air, dry-bulb temperature in deg C.
Control settings.
Unloader set points.
Low-pressure-cutout set point in kPa.
High-pressure-cutout set point in kPa.
Suction pressure in kPa.
Suction temperature in deg C.
Condenser refrigerant pressure in kPa.
Condenser refrigerant temperature in deg C.
Oil pressure in kPa.
Oil temperature in deg C.
Voltage at each connection.
Amperage for each phase.
Kilowatt input.
Crankcase heater kilowatt.

Number of fans.

Condenser fan rpm.
Condenser fan airflow rate in m³/sec.
Condenser fan motor make, frame size, rpm, and horsepower.
Condenser fan motor voltage at each connection.
Condenser fan motor amperage for each phase.

VIBRATION MEASUREMENT REPORTS:

Date and time of test.

Vibration meter manufacturer, model number, and serial number.

Equipment designation, location, equipment, speed, motor speed, and motor horsepower.

Diagram of equipment showing the vibration measurement locations.

Measurement readings for each measurement location.
Calculate isolator efficiency using measurements taken.

Description of predominant vibration source.

SOUND MEASUREMENT REPORTS: Record sound measurements on octave band and dBA test forms and on an NC or RC chart indicating the decibel level measured in each frequency band for both "background" and "HVAC system operating" readings. Record each tested location on a separate NC or RC chart. Record the following on the forms:

Date and time of test. Record each tested location on its own NC curve.

Sound meter manufacturer, model number, and serial number.

Space location within the building including floor level and room number.

Diagram or color photograph of the space showing the measurement location.

Time weighting of measurements, either fast or slow.

Description of the measured sound: steady, transient, or tonal.

Description of predominant sound source.

INSTRUMENT CALIBRATION REPORTS:

Report Data:

Instrument type and make.
Serial number.
Application.
Dates of use.
Dates of calibration.

METHOD OF MEASUREMENT. This work will be measured for payment on a lump sum basis for the work completed in accordance with the Contract Documents and as directed by the Engineer.

BASIS OF PAYMENT. The lump sum price bid for Testing, Adjusting, and Balancing (TAB) shall include the cost of all labor, materials, equipment, accessories, and appliances necessary to complete the work as shown on the contract drawings, and as specified in the referenced section.

Monthly payment will be made for this item in proportion to the total amount of work completed up to a limit of 50% of the lump sum price bid. The remaining 50% of the lump sum price bid shall be paid after all systems in the Testing, Adjusting, and Balancing have been tested and accepted by the Owner, and the O&M training program is completed and accepted by the Owner.
Before the first payment estimate is issued for work under this item, the Contractor shall furnish to the Engineer a detailed estimate of quantities and prices for all materials and labor included under this item, which shall aggregate the contract lump sum price bid for this item. This estimate shall be made out in such form as required and, if requested, supported by such evidence of its correctness as the Engineer may direct. This evidence shall include certified copies of subcontracts.

The Contractor agrees that this detailed estimate shall not become effective until it has been approved by the Engineer, who shall have the right to revise the estimate as, in their judgment, may be required to make the various subdivisions of work conform to their value. The approved detail estimate shall be used as a basis for monthly payment for work completed under this item. The proportionate share for bond premiums for this item shall not be listed as a separate item but its cost shall be distributed pro rate throughout the estimate for this item.