SECTION 23 0593 - TESTING, ADJUSTING AND BALANCING FOR HVAC

Maintain Section format, including the UH master spec designation and version date in bold in the center columns of the header and footer. Complete the header and footer with Project information.

Edit and finalize this Section, where prompted by Editor's notes, to suit Project specific requirements. Make selections for the Project at text identified **in bold**.

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

Delete hidden text after this Section has been edited for the Project.

PART 1 – GENERAL

1.1 RELATED DOCUMENTS:

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

B. The Contractor's attention is specifically directed, but not limited, to the following documents for additional requirements:

1. The current version of the *Uniform General Conditions for Construction Contracts*, State of Texas, available on the web site of the Texas Facilities Commission.
2. The University of Houston's *Supplemental General Conditions and Special Conditions for Construction.*

1.2 DESCRIPTION OF WORK:

A. General: HVAC systems and equipment on this project shall be successfully proof, acceptance and operationally tested and balanced, as applicable prior to acceptance of the project by the Owner.

B. Proof and Acceptance Testing: Provide proof and acceptance testing of HVAC systems and equipment during the construction process to verify that systems are installed and function as specified. Piping systems shall not be insulated, covered up, or placed in service until piping has been successfully tested, flushed, cleaned and water-treated, as applicable. Ductwork shall not be externally insulated, covered up or placed in service until it has been successfully tested. Equipment shall not be placed in service until it has been checked out, tested and adjusted, as applicable. Provide required proof and acceptance testing, as indicated.

C. System Adjustments/Operational Certification: Provide required system adjustments and certify that each HVAC system is operational, as specified.

D. Operational Testing and Balancing: All new **[and modified existing]** HVAC air, **[water]** and control systems on the project shall be operationally tested and balanced prior to acceptance by the Owner. Systems shall be made operational and prepared for operational testing and balancing. Operational testing and balancing is specified in shall be provided by an independent Testing and Balancing (TAB)

Consultant who shall be contracted directly to and paid by **[the Owner and shall have no contractual relationship or obligation to the General Contractor or Division 23 Contractor] [the General Contractor] [the Division 23 Contractor]**. The Owner will provide the services of designated Owner's Representatives (OR) who will observe selected testing and balancing for the systems installed on the project. Provide coordination with and preparations for the TAB Consultant's operational testing and balancing work as specified.

E. Project Completion: Provide project completion services as specified.

1.3 QUALITY ASSURANCE:

A. References: Comply with applicable requirements and recommendations of the following:

1. AABC "National Standards for Total System Balance."
2. ASHRAE 111: Testing, Adjusting, and Balancing of Building HVAC Systems.
3. NEBB "Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems."
4. ASHRAE Handbooks.

B. Personnel: Submit evidence to show that the personnel who will actually test systems and equipment are qualified. Evidence showing that the personnel have passed the tests required by the Associated Air Balance Council (AABC) or the National Environmental Balancing Bureau (NEBB) will be sufficient. Architect and Owner reserve the right to require that the originally approved personnel be replaced with other qualified personnel if, in their opinion, the original personnel are not qualified or are not properly conducting the system testing, adjusting and Balancing.

1.4 ACTION SUBMITTALS:

A. Testing Procedures: Submit proposed proof and acceptance testing and operational certification procedures for review at least [**30**] [**Insert days**] days prior to conducting any testing or certification.

B. Reporting Forms: Submit proposed forms to be used in recording test and certification data and results for review at least 30 days prior to conducting any testing on the project. AABC or NEBB forms are acceptable.

C. Test and Certification Data and Results: Submit complete data and certified test results for each test performed, including, but not limited to:

1. Title Page: Provide the following information on a title page:

a. Title
b. System(s) tested
c. Testing Company Name
d. Testing Company Address
e. Testing Company Telephone Number
f. Testing Company Contact Person
g. Project Name

h. Project Location
i. Project Architect
j. Project Engineer
k. Project General Contractor
l. Other pertinent information

2. Instrument List: Provide the following information on an instrument listing page:

a. Instruments
b. Manufacturers
c. Models
d. Serial Numbers
e. Ranges
f. Calibration Dates

3. Test/Certification Data and Results: Provide pages with applicable test and certification data and results including, but not limited to the following:

a. Test/certification performed.
b. Test/certification procedure.
c. System and area tested.
d. Date(s) and time(s) of test.
e. Weather conditions.
f. Test/certification criteria.
g. Test/certification results.
h. Additional pertinent information.

D. Operational Certification: Submit an operational certification which documents that all equipment and systems have been fully tested to verify proper operation in accordance with the design shown in the Construction Documents and manufacturer's recommendations.

E. Certification of TAB Preparations: Submit letter certify, by system and area, when coordination is completed and systems have been fully proof/acceptance tested and are operational and prepared for acceptance testing and balancing by the TAB consultant.

F. Certification: Certifications stating that submitted data is true and correct shall be provided for all submittals under this Section. Certification shall be executed by an authorized officer if the Contractor is a corporation, by a partner if the Contractor is a partnership, by the Owner if the Contractor is a sole proprietorship or by the authorized representative if the Contractor is a joint venture.

G. Calibration List: Submit a listing of testing devices to be used for the project. Listing shall include documentation that devices are properly calibrated.

H. Test/Certification Log: Maintain a test/certification log at the site to document the results of all successful and unsuccessful testing/certification as it is performed. This log shall be available for review by the Architect and Owner and a copy of the log shall be submitted prior to the Substantial

Completion inspection. A space shall be provided on the test/certification log for signoff by the Owner and Architect

I. Operating and Maintenance Manuals: Approved copies of Testing Procedures, Test and Certification Data and Results, Operational Certification and Test/Certification Log shall be included in the Operating and Maintenance Manuals specified in Section 23 0100 "Mechanical Scope of Work."

1.5 NOTIIFICATION:

A. General: Notify the Architect and Owner in writing two weeks prior to all scheduled testing and certification to allow time to schedule witnessing of testing and certification.

PART 2 - PRODUCTS

2.1 TESTING MATERIALS:

A. General: Provide all materials, equipment and personnel for all required proof and acceptance testing and preparation for operational testing and balancing, including all required retesting and repreparation.

B. Products: Tested products which fail to provide acceptable test results shall be repaired or replaced with suitable materials and then retested until acceptable test results are obtained.

PART 3 - EXECUTION

3.1 PROOF AND ACCEPTANCE TESTING:

A. General: Proof and acceptance tests shall be made during the course of construction as specified and in other Sections of this Division and as required by Authorities having jurisdiction. Such tests shall include all provisions, personnel, material and equipment required to perform tests until satisfactory results are obtained. Any defects detected during testing shall be satisfactorily repaired or the equipment involved shall be replaced and the tests re-executed.

B. Tests: Testing shall include, but not be limited to, all items listed in other Sections of this Division, and the following:

1. Hydrostatic Testing: All pressurized piping [**(except diesel fuel, HVAC control air)**] shall be hydrostatically leak-tested prior to enclosure or cover-up. Piping shall be leak tested for 24 hours under a hydrostatic pressure of 150% of the system design working pressure, but not less than 225 psi. The Architect and Owner shall be notified prior to all hydrostatic tests and may elect to witness any of the tests. Water shall not be drawn off of the piping and the piping shall not be covered up until it has been approved by Architect or Owner. Care shall be taken to protect any equipment which may be damaged by hydrostatic testing. Refer to Section 23 2000 "HVAC Piping Systems" for additional test requirements. Following successful testing, chilled [, **condenser**] [**and heating hot**] water [**and steam and steam condensate piping**] shall be flushed and chemical treated as specified in Sections **[23 0300,][23 2000,]**and **[23 2010]**.

2. Pneumatic Testing: All [**HVAC control air, refrigerant**] piping shall be leak tested prior to enclosure or cover-up. [**Refrigerant piping shall be leak-tested using dry compressed nitrogen for 24 hours at 150% of system high side operating pressure.**] [**HVAC control air shall be leak tested for 24 hours under a pneumatic pressure of 150 % of system main air pressure**]. The Architect and Owner shall be notified prior to pneumatic tests and may elect to witness any of the tests. Air shall not be drawn off of piping until it has been approved by Architect or Owner. Care shall be taken to protect any equipment which may be damaged by pneumatic testing. Refer to Section 23 2000 for additional testing requirements.
3. **[Refrigerant Leak Testing: Leak test and check refrigerant charge on all refrigeration systems at final acceptance and at the end of the warranty period. Repair any leaks found and properly charge affected systems with refrigerant and oil. Certify that all refrigeration systems are properly charged and free from leaks at final acceptance and at the end of warranty (one year from final acceptance).]**
4. **[Chiller Capacity Testing: Provide centrifugal chiller field capacity testing as specified in Section 23 6410.]**
5. Chiller Oil Sample Testing: Provide oil sample testing and reports as specified in Section 23 6410.
6. Cooling Tower Capacity Testing: Provide cooling tower field capacity testing as specified in [Section 23 6514].
7. Water Testing: Provide water analysis and testing as specified in Section 23 6000.
8. Fire, Smoke and Fire/Smoke Damper Testing: Provide fire, smoke and fire/smoke damper testing and certification as specified in Section 23 3114.
9. **[Stair Pressurization System Testing: he operation of the pressurization system in each pressurized stair shall be tested as follows:]**
   a. **[Verify fan stop/start control from the fire alarm system, including firefighters' override.]**
   b. **[Verify duct smoke detector shutdown of fan.]**
   c. **[Verify fire alarm system monitoring of fan status.]**
   d. **[Verify proper operation of the fan inlet damper [and that the stair relief damper is closed with the fan off].**
   e. **[Certify the results of all tests and verification hereinabove, for each pressurized stair.]**
10. **[Smoke Management System Testing: The operation of the smoke management system [on each floor] [and in the atrium] [in each building smoke compartment] shall be tested as follows:]**
    a. **[Verify smoke management activation/deactivation from the fire alarm system, including firefighters' override.]**
    b. **[Verify fan start/stop control from the fire alarm system, including proper speed selection and firefighter's override and speed selection.]**
    c. **[Verify fire alarm system monitoring of fan status.]**

d. [For each floor [and the atrium], verify that smoke removal dampers [and makeup dampers], as applicable, open properly upon signal from the fire alarm system, including firefighter's override.]

e. [Certify the results of all tests and verification hereinabove, for each smoke compartment [and the atrium].

11. Fire Alarm System Interface: Provide testing, in conjunction with the Fire Alarm System functional testing specified in Division 26, to verify that all fire alarm related HVAC control functions and shutdowns operate as specified in Division 23, Division 26 and as shown on the Drawings.
12. Duct Leakage Testing: Provide duct integrity and leakage testing as specified elsewhere in Division 23.
13. Operational Testing: Test all systems and components installed in the building to verify proper operation is provided as described in the specifications and manufacturer's recommendations.
14. Vibration Isolation Certification: Provide certification of the installation of vibration isolation as specified in Section 23 0548.
15. **[BMS Testing and Certification: A complete BMS checkout and test shall be performed to demonstrate and certify that the BMS is 100% operational and adjusted upon completion of the installation and that it complies with all applicable codes and specification requirements.] The Division 23 and Division 25 Contractors shall participate in the BMS testing and certification process to assure that HVAC systems, equipment and related BAS interfaces perform as specified.]**

a. [The system checkout and test shall be performed within 30 days of the completion of system installation, adjustment and commissioning. Testing shall be performed in two parts and two-way radios for use by test observers shall be provided. The first part of the test shall be a full test of all system components, functions, and alarms. All affected subcontractors shall participate in this test. Test results shall be certified and submitted to the Architect. This test shall be the basis for System Acceptance. The second part of the test shall be a demonstration of basic system functions and alarms for the Architect and Owner's Representative.]

b. [TAB shall coordinate the test schedule with the Contractors required to be present for a complete and functional test.]

c. [The system checkout and test shall be a comprehensive 100% inspection and functional test of all equipment and software and shall include, but not be limited to, the following:]

1) **[Verification of manual and program control of all start/stop and alarm points, including status indication and alarms.]**
2) **[Verification of all controlled points including setpoint and actual point readouts, remote setpoint change and point alarm.]**
3) **[Verification of all alarm points.]**
4) **[Verification that all system annunciation text and messages are correct and appropriate.]**

5) **[Functional test of the normal and emergency power building start-up and shutdown routines.]**
6) **[Testing to verify that all systems on emergency power operate as specified in the sequence of operation.]**
7) **[Testing to verify that all control functions specified in the sequence of operation are provided and fully functional as specified and required.]**
8) **[Testing to verify that all specified software is provided and fully implemented.]**

d. [Submit a letter to the Architect for review prior to final acceptance certifying that the BMS is properly and fully installed and fully adjusted and calibrated to operate as according to Contract Documents.]

16. Emergency Power Operation Testing: Testing of BCAS and HVAC system operation under emergency power shall be coordinated such that the testing is conducted along with the emergency power system testing and certification.

17. Sound Testing: Sound Testing will be performed at [**8**][**Insert number here**] locations on the project as selected by the Architect for the following areas:
    a. Inside mechanical equipment areas and adjacent to mechanical equipment being tested to validate the scheduled and specified equipment sound requirements. Test at appropriate distances.
    b. Acoustically sensitive areas such as performing arts spaces, classrooms, conference rooms, private offices and libraries.

C. Authorities Having Jurisdiction: Perform any additional proof and acceptance testing required by AHJ.

3.2 SYSTEM ADJUSTMENTS:

A. General: Systems installed under this Division, except HVAC air **[and water]** balancing, shall be adjusted by Contractor to provide proper operation.

B. Adjustments: Systems to be adjusted shall include, but not be limited to:
1. Steam System Adjustments: The steam boilers and steam pressure reducing valves shall be adjusted to provide the scheduled steam pressure in the building supply systems, prior to Final Acceptance.
2. Miscellaneous Controls and Alarms: Adjust and test all miscellaneous pressure, temperature, flow, level, refrigerant and similar controls and related alarm systems and monitoring to provide proper operation.
3. Control Balancing: All control systems and equipment installed on the project shall be programmed, calibrated and/or adjusted to provide proper operation or function in accordance with the drawings, specifications and manufacturer's recommendations. This programming, calibration and adjusting shall be completed as part of the preparations for air and water system balancing specified.

3.3 OPERATIONAL CERTIFICATION:

A. HVAC Systems: Operationally test project HVAC systems to demonstrate satisfactory operation. Operation tests shall include, but not be limited to:

1. Steam boiler operation and discharge pressure.
2. Steam pressure at inlet and discharge from each steam PRV.
3. Steam boiler feed pump operation and alarms.
4. Steam condensate return unit operation and alarms.
5. Heating water boiler operation, interlocks, controls and alarms.
6. Chiller operation, interlocks, controls and alarms.
7. Cooling tower operation, fill valves and vibration shutdown.
8. HVAC control air compressor and air dryer operation.
9. HVAC air-handling systems operation, interlocks, controls and alarms.
10. Results of other HVAC system tests.
11. Test results for piping system tests.
12. Test results for ductwork leakage tests.
13. Test results for HVAC system water treatment.
14. Time, date and duration of each test.

3.4 PREPARATION FOR OPERATIONAL TESTING AND BALANCING:

A. General: All air **[, water]** and control systems installed on the project shall be balanced and/or adjusted to provide proper operation or function in accordance with the drawings, specifications and manufacturer's recommendations. Refer to Section 23 0593 for HVAC air **[, water]** and control system operational testing and balancing. System startup and preparation for operational testing and balancing shall be provided under this Section.

B. Provisions for Operational Testing and Balancing: Install all provisions for operational testing and balancing as shown on the drawings, specified and required by the TAB Consultant. These provisions shall include, but not be limited to all control, regulating and readout devices necessary to operationally test and balance all air **[, water]** and control systems including, but not limited to: thermometers; pressure gauges; **[air monitoring stations;] [flow meters;] [flow venturis;]** balancing valves; air volume, splitter and extractor dampers; pressure taps; temperature taps and wells; pitot tube ports; and other necessary provisions.

1. The Division 23 Contractor shall notify the Engineer in writing and receive clarification in writing prior to submitting a bid, if in the Contractor's opinion, any required provisions have been omitted. Submission of a bid constitutes an agreement that all provisions required for operational testing and balancing shall be provided at no cost to the Owner or Architect/Engineer, regardless of whether such provisions are specifically shown on the drawings or in the specifications.

C. Coordination and Scheduling: Coordinate and schedule preparations for operational testing and balancing with the TAB Consultant. This coordination and scheduling shall include, but not be limited to:

1. Coordinate exact locations of operational testing and balancing provisions with the TAB Consultant.
2. Sequence completion of preparation for operational testing and balancing to allow adequate time for the TAB Consultant to complete operational testing and balancing prior to project substantial completion.

D. TAB Consultant Input: Provide input to the TAB Consultant including, but not limited to:

1. Fan and pump curves and performance data.
2. Performance data on **[boilers,]** chillers, heat exchangers, cooling towers and coils.
3. All approved HVAC Shop Drawings.
4. Belt drive data on all belt driven equipment.
5. As-built drawings accurately showing locations of all measuring and balancing devices, air vents and drain valves.
6. Control diagrams and sequence of operation.
7. Copies of all HVAC RFI's and Change Orders.
8. Additional input required by the TAB Consultant.

E. TAB Consultant Noted Deficiencies: Correct any deficiencies noted to the TAB Consultant during the operational testing and balancing process. Corrections shall be made in a timely manner so as not to impede the work of the TAB Consultant. These corrections shall include, but not be limited to:

1. Relocating test points and sensors/controllers which are installed or positioned in a manner which prevents correct measurement or sensing of temperatures, pressures, humidity, etc. and to provide sufficient access to these devices.
2. Corrections to control functions which do not operate in accordance with the sequence of operation.
3. Recalibration of control devices.
4. Relocation of air and water taps which are installed or positioned in a manner which does not allow design flows to be obtained in the tap.
5. Relocation of balancing and control devices to provide sufficient access to these devices.
6. Addition of required balancing dampers and valves.

F. Preparation for Air Balancing: All **[Base Building and new]** air systems shall be completely installed, operational and prepared prior to commencing with air balancing. The minimum steps required for preparation for air balancing shall include, but not be limited to:

1. Inspection: Inspect and certify in writing that the complete air system including, but not limited to: air handling equipment, fans, terminal units, coils, ductwork, air devices, dampers, controls, balancing devices, access doors, test ports, return air paths, partitions to deck and doors in partitions to deck are installed and operational, as applicable.
2. Operation: Certify that the complete air system is operable and operates in a safe and normal manner.
3. Dampers: Inspect and certify in writing, that all required volume, splitter, extractor, fire, smoke and fire/smoke dampers are installed, that all balancing dampers are in the open and locked position, that all fire dampers are open, that all fire/smoke, smoke and control dampers open

and close properly in response to control sequences and that all access doors are closed and sealed.

4. Fans: Adjust and verify in writing that all fans are operating properly, are rotating at design fan RPM in the proper direction, are free from vibration, have proper belt tension and that properly sized overload elements are installed in motor starters, where motors are not self-protected. Record motor nameplate data and measured voltage and amperage on each phase at initial motor startup.
5. **[Variable Speed Drives (VSD's): Verify in writing that all VSD's have been factory pre-tested prior to shipment and field tested for proper operation and controls interface.]**
6. Controls: Verify in writing that all required air system controls, interlocks and safety devices are fully operational and that all controlling devices are calibrated and set for designed conditions.
7. Testing: Verify in writing that all specified duct leakage and fire, smoke and fire/smoke damper testing has been successfully completed and that duct systems are clean and free of any dirt or debris.
8. Cleaning: Install clean air filters in all equipment and, where equipment has been operated, clean coils and vacuum equipment interior in preparation for balancing. Comb out any coiled fins damaged by construction or cleaning. The Engineer and OR shall be the final decision makers on whether coils and equipment must be cleaned prior to balancing.
9. Notification: Notify Architect **[Owner]**and TAB Consultant in writing when all items required have been completed for a specific air system and certify that the system is operational and prepared for operational testing and balancing.

G. Preparation for Chilled**[, Condenser] [and Heating Hot]** Water Balancing: All **[Base Building and new]** chilled**[, condenser] [and heating hot]** water systems shall be completely installed, operational and prepared prior to commencing with water balancing. The minimum steps required for preparation for water balancing shall include, but are not limited to:

1. Inspection: Inspect and certify in writing that the complete water system including, but not limited to pumps, heat exchangers, coils, piping, valves, meters, venturis, gauges, thermometers, test ports and controls are installed and operational, as applicable.
2. Operation: Certify that the complete HVAC water system is operable and operates in a safe and normal manner.
3. System Filling: Verify and certify in writing that water systems are full of water and free of air, that water treatment has been installed, that properly operating air vents are installed at all system high points, that drain valves are installed at all system low points and that expansion/compression tanks are properly charged and are not water logged.
4. Valves: Inspect and certify in writing that all stop, isolation, balancing and control valves are open and that all bypass valves are closed. Mixing valves shall be open to system components.
5. Pumps: Check and certify in writing that pumps are properly aligned, that pump bases have been grouted, that pumps are rotating in the correct direction, that pumps are free from vibration and that properly sized overload elements are installed in motor starters. Record motor nameplate data measured and voltage and amperage on each phase at initial motor startup.
6. **[Variable Speed Drives (VSD's): Verify in writing that all VSD's have been factory pre-tested prior to shipment and field tested for proper operation and controls interface.]**

7. Controls: Verify in writing that all required water system controls, interlocks and safety devices are fully operational and that all controlling devices are calibrated and set for design conditions.
8. Testing: Verify in writing that all specified piping system leakage testing has been successfully completed.
9. Cleaning: Verify in writing that all specified system flushing and cleaning has been completed and that all system strainers have been removed, cleaned and reinstalled.
10. Notification: Notify Architect **[Owner]**and TAB Consultant in writing when all items required have been completed for a specific HVAC water system and certify that the system is operational and prepared for operational testing and balancing.

3.5 PROJECT COMPLETION:

A. General: Prior to Project Substantial Completion, provide project completion services necessary to complete the project including, but not limited to:

1. Sheave Replacement: Replace adjustable sheaves with permanent fixed position sheaves. Fixed sheaves shall match the RPM set on the variable pitch sheaves by the TAB Consultant.
2. Completion Reports: After all testing, balancing and adjusting, furnish all labor, materials and devices necessary to prepare a completion report with the following information.

    a. Motor data on all motors installed on the project. Motors shall be listed by the device on which they are installed and information provided shall include: horsepower, speed, type, location, rated full load amperage, rated voltage, actual measured amperage for each leg and actual measured voltage for each leg.
    b. Belt and drive data for all belt driven equipment installed on the project. Data shall be listed by the device on which the belts and drive are installed and information provided shall include: number of belts, size of belts, size and type of drive installed, motor rpm and driven device rpm.
    c. Fan speed data shall be measured and recorded in rpm, for each belt drive and variable speed fan.
3. **[Re-adjustment: During the period between 6 months to one year after Final Acceptance, adjust each fan and blower to a new rotative speed as selected by the Owner. Provide two sets of fixed drives and necessary labor for installation to accomplish all required fan speed adjustments during this period.]**

END OF SECTION 23 0593