

SECTION 23 05 93 - TESTING, ADJUSTMENT AND BALANCING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS:

- A. The Conditions of the Contract and applicable requirements of Division 1, "General Requirements", and Section 23 01 00, "Mechanical General Provisions", govern this Section.

1.2 DESCRIPTION OF WORK:

- A. General: All HVAC, plumbing and fire protection 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: The Division 23 Contractor shall provide proof and acceptance testing of HVAC, plumbing and fire protection 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. The Division 23 Contractor shall provide all required proof and acceptance testing, as specified hereinbelow.
- C. System Adjustments/Operational Certification: The Division 23 Contractor shall provide required system adjustments and certify that each HVAC, plumbing and fire protection system is operational, as specified hereinbelow.
- 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 by the Division 23 Contractor. Operational testing and balancing is specified in Section 230593 and 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. The Division 23 Contractor shall provide coordination with and preparations for the TAB Consultant's operational testing and balancing work as specified hereinbelow.
- E. Project Completion: The Division 23 contractor shall provide project completion services as specified hereinbelow.

1.3 QUALITY ASSURANCE:

- A. References: Comply with applicable requirements and recommendations of the following:
 - 1. AABC - 1989 Fifth Edition: National Standards for Testing and Balancing Heating, Ventilating and Air Conditioning Systems.
 - 2. NEBB - Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems.
 - 3. ASHRAE - 1991 HVAC Applications Handbook: Chapter 34, Testing, Adjusting and Balancing.
 - 4. SMACNA - HVAC SYSTEMS Testing, Adjusting and Balancing.
- 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. The Engineer reserves 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.

1.4 SUBMITTALS:

- A. Testing Procedures: Submit six copies of all proposed proof and acceptance testing and operational certification procedures to the Engineer for review at least 30 days prior to conducting any testing or certification.
- B. Reporting Forms: Submit four copies of proposed forms to be used in recording test and certification data and results to the Engineer for review at least 30 days prior to conducting any testing on the project. Data forms from AABC or NEBB will be acceptable.
- C. Test and Certification Data and Results: Submit six copies of 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 six certified copies of 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: The Division 23 Contractor shall certify in writing to the Engineer and TAB consultant, 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 four copies of a listing of testing devices to be used for the project to the Engineer for approval. Listing shall include documentation that devices are properly calibrated.
- H. Test/Certification Log: The Contractor shall 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 Engineer and a copy of the log shall be submitted to the Engineer prior to the Substantial Completion inspection. A space shall be provided on the test/certification log for signoff by the OR/Engineer.
- 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 01 00

1.5 NOTICE:

- A. General: Notify the Engineer in writing two weeks prior to all scheduled testing and certification to allow time for Engineer to schedule witnessing of testing and certification, where elected by the Engineer.

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 re-preparation.
- 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 hereinbelow and in other Sections of this Division and as required by Authorities having jurisdiction. Such tests shall be conducted by this Division as a part of the Work and 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, control air, compressed air, laboratory gas, refrigerant and natural gas piping)] 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 Engineer 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 the Engineer or OR. Care shall be taken to protect any equipment which may be damaged by hydrostatic testing. Refer to Sections 22 00 00, 22 02 00, 22 04 00 and 23 20 00 for additional test requirements. Following successful testing, domestic water piping shall be sterilized or specified in Sections 23 03 00 and 22 00 00 and chilled [, condenser] [and heating hot] water

- [and steam and steam condensate piping] shall be flushed and chemical treated as specified in Sections 23 03 00, 23 20 00 and 23 20 10.
2. **Pneumatic Testing:** All [diesel fuel, control air, compressed air, refrigerant, laboratory gas and natural gas] piping shall be leak tested prior to enclosure or cover-up. [Diesel piping shall be leak tested for 24 hours under a pneumatic pressure of 150 psi.] [Refrigerant piping shall be leak-tested using dry compressed nitrogen for 24 hours at 150% of system high side operating pressure.] [Compressed air and laboratory gas piping shall be leak tested for 24 hours under a pneumatic pressure of 150 psi.] [Natural gas piping shall be leak tested for 24 hours under a pneumatic pressure of five times the service pressure but not less than 100 psi or a higher pressure if required by the natural gas utility.] The Engineer 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 the Engineer or OR. Care shall be taken to protect any equipment which may be damaged by pneumatic testing. Refer to Sections 22 00 00, 22 15 14, 22 02 00 and 23 20 00 for additional testing requirements.
 3. **Leak Testing:** All soil, waste, [acid waste,] storm and vent [and acid vent] piping shall be leak tested by temporarily plugging piping stacks and filling the system to be tested with standing water for 3 hours. Water shall not be drawn off of piping and the piping shall not be covered up until it has been approved by the Engineer or OR. Additional testing shall also be provided as required by the local Plumbing Inspection Department. Submit the proposed test procedure and grouping to the Engineer for review. Refer to Section[s] 22 00 00 [and 22 03 00] for addition test requirements.
 4. **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. The Contractor shall 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).]**
 5. **Fire Protection System Hydrostatic Testing:** All fire protection piping shall be hydrostatically tested as specified herein above and additional tests shall be performed as Specified in Sections 21 12 00, 21 13 13, 21 13 16 and Section 21 13 18.
 6. **Halon Fire Suppression System Testing:** Provide testing and certification as specified in Section 21 22 00.
 7. **Fire Pump Testing:** Provide testing and certification of fire pump operation and capacity as specified in Section 21 30 00.
 8. **Domestic Water Pumping System Testing:** Provide testing and certification as specified in Section 22 10 00.
 9. **Sump Pump and Sewage Ejector Testing:** Provide testing and certification as specified in Section 22 11 23.
 10. **Fuel Oil System Testing:** Provide fuel system testing as specified in Sections 22 02 00.
 11. **Chiller Capacity Testing: Provide centrifugal chiller field capacity testing as specified in Section 23 64 10.]**
 12. **Chiller Oil Sample Testing:** Provide oil sample testing and reports as specified in Section 23 64 10.
 13. **Cooling Tower Capacity Testing:** Provide cooling tower field capacity testing as specified in [Section 23 65 00].
 14. **Water Testing:** Provide water analysis and testing as specified in Section(s) [22 31 00, 22 50 00,] [and] 23 60 00.
 15. **Air Handling Unit Acoustical Performance Testing: Provide factory acoustical performance testing for air handling units as specified in Section 23 73 13.]**

16. Fire, Smoke and Fire/Smoke Damper Testing: Provide fire, smoke and fire/smoke damper testing and certification as specified in Section 23 31 14.
17. **Stair Pressurization System Testing**: The 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.]
18. **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].
19. 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 [Section 23 06 00] [Division 23], Division 26 and as shown on the Drawings.
20. Duct Leakage Testing: Provide duct integrity and leakage testing as specified elsewhere in Division 23.
21. Operational Testing: The Contractor shall test all systems and components installed in the building to verify proper operation is provided as described in the specifications and manufacturer's recommendations.
22. Vibration Isolation Certification: Provide certification of the installation of vibration isolation as specified in Section 23 05 48.
23. **BCAS Testing and Certification**: A complete BCAS checkout and test shall be performed by the Division [23] Contractor to demonstrate and certify that the BCAS is 100% operational and adjusted upon completion of the installation, and that it complies with all applicable codes and specification requirements.] [The Division 23 Contractor shall participate in the BCAS testing and certification process to assure that HVAC, plumbing and fire protection systems, equipment and related BCAS 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 Engineer. This test shall be the basis for the System Acceptance document specified in Section [23 06 00] [_____]. The second part of the test shall be a demonstration of basic system functions and alarms for the Engineer and Owner's Representative.]

- b. [This contractor shall coordinate the test schedule with the General Contractor, Electrical Contractor, Mechanical Contractor, Fire Protection Contractor and other 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 four copies of a letter certifying that the BCAS is properly and fully installed and fully adjusted and calibrated to operate as specified to the Engineer for review prior to final acceptance.]**
24. Emergency Power Operation Testing: Testing of BCAS, HVAC, plumbing and fire protection system operation under emergency power shall be coordinated with the Division 16 Contractor such that the testing is conducted along with the Division 16 emergency power system testing and certification.
25. Sewer Rodding: All sanitary and storm sewer piping shall be free of obstructions both inside the building and to the points of connection to public utility systems. If blockage develops in any sanitary or storm piping within the warranty period and the blockage is due to construction related debris or defects, this Contractor shall be responsible for the cost of rodding out the piping to remove the blockage or obstruction. The rodding shall be done at no additional cost to the Owner or Engineer. Notify the Engineer prior to proceeding with rodding of any piping.
- C. Authorities Having Jurisdiction: The Division 23 Contractor shall also perform any additional proof and acceptance testing required by all applicable Authorities having jurisdiction over the project.

3.2 SYSTEM ADJUSTMENTS:

- A. General: Systems installed under this Division, except HVAC air **[and water]** balancing shall be adjusted by the Division 23 Contractor to provide proper operation.
- B. Adjustments: Systems to be adjusted shall include, but not be limited to:
 - 1. Domestic Hot Water System Balancing and Adjustments: Water flow through the domestic **[and kitchen]** water heaters shall be balanced to provide an equal volume through each water heater. Water heater thermostats **[and circulating pump aquastats]** shall be adjusted to provide a true **[115°F] [120°F] [and] [140°F]** hot water supply in the building domestic **[and kitchen]** hot water loop[s]. Hot water system balancing valves shall be adjusted to provide indicated flows, prior to Final Acceptance.
 - 2. 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.
 - 3. 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.
 - 4. 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 hereinbelow.

3.3 OPERATIONAL CERTIFICATION:

- A. General: Submit HVAC, plumbing and fire protection systems to operational tests to demonstrate satisfactory system operation.
- B. HVAC Systems: Operationally test project HVAC systems to demonstrate satisfactory operation. Operation tests shall include, but not be limited to:
 - 1. Boiler operation and discharge pressure.
 - 2. Steam pressure at inlet and discharge from each steam PRV.
 - 3. Boiler feed pump operation and alarms.
 - 4. Condensate return unit operation and alarms.
 - 5. Chiller operation, interlocks, controls and alarms.
 - 6. Cooling tower operation, fill valves and vibration shutdown.
 - 7. Control air compressor and air dryer operation.
 - 8. Results of other HVAC system tests.
 - 9. Test results for all piping system tests.
 - 10. Test results for all ductwork leakage tests.
 - 11. Test results for HVAC system water treatment.
 - 12. Time, date and duration of each test.
- C. Plumbing Systems: Operationally test project plumbing systems to demonstrate satisfactory operation. Operational testing shall include, but not be limited to:
 - 1. Water pressure at inlet and discharge of each PRV.
 - 2. Water pressure at most remote and highest fixtures.
 - 3. Operation of each fixture and fixture trim.
 - 4. Operation of each valve, hydrant and faucet.
 - 5. Operation of each backflow preventer and vacuum breaker.
 - 6. Operation of each floor and hub drain by flooding with water.
 - 7. Operation of each trap primer.
 - 8. Operation of all pumps and related controls and alarms.
 - 9. Suction and discharge pressure at each pump.

10. Service water pressure.
11. **[Operation of house tank fill valves and alarms.]**
12. **[Operation of water softener and inlet and outlet water sample hardness analysis.]**
13. Operation of domestic water heaters and supply/return water temperature at each heater.
14. **[Operation of sump pumps and sewage ejectors including lead/lag and level controls and alarms.]**
15. **[Operation of [medical] [laboratory] pumping systems and related alarms. Pressures/Vacuum at system inlets/outlets.]**
16. **[Medical gas piping system alarms.]**
17. **[Fuel oil system controls, monitoring and alarms. Proper operation of fuel oil return system.]**
18. Results of other required plumbing system tests.
19. Test results for all piping system leakage tests.
20. Test results for disinfection of domestic water system.
21. Time, date and duration of each test.

D. Fire Protection Systems: Operationally test project fire protection systems to demonstrate satisfactory operation. Operational testing shall include, but not be limited to:

1. Fire Service water pressure.
2. Operation of fire and jockey pumps.
3. Operation of fire protection/suppression systems.
4. Suction and discharge pressure at each pump.
5. Results of fire pump flow test.
6. Results of other required fire protection system tests.
7. Test results for all piping system leakage tests.
8. Test results for disinfection of fire water systems.
9. 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 230593 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: The Division 23 Contractor shall 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: The Division 23 Contractor shall 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:** the Division 23 Contractor shall 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:** The Division 23 Contractor shall 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 the Engineer and TAB Consultant in writing when all items required in paragraphs 3.04B, 3.04C, 3.04D 3.04E and 3.04F/1-8 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 the Engineer and TAB Consultant in writing when all items required in paragraphs 3.04B, 3.04C, 3.04D, 3.04E and 3.04G/1-9 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, the Contractor shall 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, the Contractor shall 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.

[INCLUDE THE FOLLOWING ON SHELL SPACE OFFICE BUILDINGS ONLY]

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 05 93