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**PART 1 GENERAL****1.1 RELATED DOCUMENTS**

- A. The requirements of the General Conditions, Supplementary Conditions and all Division 23 Specification sections apply to all Work herein.

**1.2 SUMMARY**

- A. Provide all Pre-functional Testing, Functional Testing and Integrated Systems Testing to demonstrate proper operation as required by these Specifications, the City of San Francisco, and the authorities having jurisdiction of the HVAC system, equipment and components as indicated on the Drawings and as specified herein. Tests shall include, but not be limited to the items specified in this section and in other Division 23 Specification sections.
- B. The Division 23 Subcontractor shall take the lead responsibility for inspecting, completing and documenting the Pre-Functional Testing for the HVAC Systems to ensure the systems are fully operational and ready for Functional Testing.
- C. The Division 23 Subcontractor shall take the lead responsibility for demonstrating the operations of the HVAC systems for the Functional Tests.
- D. Testing shall in no way relieve the Subcontractor of the warranty requirements.
- E. The Subcontractor shall furnish all fuel, water and electricity required in performing the testing, balancing and adjusting of mechanical systems.

**1.3 REFERENCE STANDARDS**

- A. All testing, balancing, and adjusting shall be performed in accordance with the latest applicable industry standards, those standards referenced in the applicable Division 23 specifications, including the following:
  - 1. NEBB "Procedural Standards for Testing, Adjusting and Balancing of Environmental Systems". NEBB Contractors shall be independent from the installing HVAC contractor.
  - 2. AABC National Standards
- B. All equipment and material to be furnished and installed on this Project shall be UL or ETL listed, in accordance with the requirements of the authorities having jurisdiction and suitable for its intended use on this Project.

**1.4 SUBMITTALS**

- A. The following submittal data shall be furnished according to the General Conditions, Section 23 00 10, and in accordance with the Subcontractor Scheduling Procedures in Section 23 00 20 titled "HVAC Scope of Work" and shall include, but not be limited to:
  - 1. Proposed test procedures, recording forms, test equipment, and list of personnel and qualifications for all tests proposed. Refer to Section 26 08 13 titled "Testing" for additional requirements.
  - 2. Water and Air Balance Procedures, Recording Forms and Test Equipment.
  - 3. Vibration and Alignment Readings.
  - 4. Vibration and Alignment Testing Agency Qualifications.
  - 5. Leak Testing Report for each refrigeration system.
  - 6. Sound Level Reading Test Equipment and Reporting Forms.
  - 7. Fuel System Testing Report.
  - 8. Pump Test Data.
  - 9. Pump and Motor Coupling Alignment Reports.
  - 10. Hydrostatic Test Logs.
  - 11. Final Air and Water Balance Readings.

**1.5 WARRANTY**

- A. Comply with the requirements of the General Conditions and Section 23 00 10.

**PART 2 PRODUCTS (Not Used)****PART 3 EXECUTION****3.1 FACTORY TESTING**

- A. All factory testing shall be performed in accordance with the latest applicable industry standards, with the manufacturer's recommendations and as specified in the applicable Division 23 Specification Sections.

**3.2 FIELD TESTING - GENERAL**

- A. During the progress of the Work, tests shall be made as specified herein and as required by authorities having jurisdiction, including local inspectors, Owner, Owner's Insuring Agency, Architect or Engineer. Tests shall be conducted by the Mechanical Subcontractor as part of the Work of this Division and shall include all qualified personnel, equipment apparatus and services required to perform the tests.
- B. Air and water flow measurements shall be made in conjunction with air and water balancing procedures as specified in this Section. Air and water balance procedures shall be performed by a National Environmental Balancing Bureau or Associated Air Balance Council certified independent testing and balancing contractor(s) in accordance with the current edition of the NEBB "Procedural Standards for Testing Adjusting and Balancing of Environmental Systems" or the AABC National Standards.
- C. The Subcontractor shall submit proposed test procedures, recording forms and testing equipment calibration certification forms for review in accordance with the Subcontractor Scheduling Procedures in Section 23 00 20 titled "HVAC Scope of Work".
- D. Leaks, damage, or defects discovered or resulting from tests shall be repaired or replaced to a like new condition. Leaky pipe joints, ductwork, etc., shall be removed and replaced with acceptable materials.
- E. All equipment and instruments required for tests as well as additional thermometer wells, gauge and instrument connections shall be installed at no additional cost to the Owner.
- F. All instruments used for testing and balancing must have been calibrated within a period of three (3) months prior to balancing. Instrument calibration shall be certified as specified in Section 23 00 10.
- G. The Subcontractor shall prove the capacity and performance and/or demonstrate operating controls and safety devices of each piece of equipment by field tests as requested and/or specified in various sections of these Specifications. All equipment and instruments required for tests as well as additional thermo wells or gauge connections shall be installed at no additional cost to the Owner. A qualified representative of the equipment manufacturer shall be present at the tests. The Engineer may witness tests, if he so desires. The Subcontractor shall notify the Engineer and Owner in writing, at least two (2) weeks prior to the start of testing. See Section 23 00 10 for additional requirements.
- H. Submit six (6) copies of each complete testing and balancing report to the Engineer for review and send two (2) copies of the report to the Owner. The Subcontractor shall submit individual testing and balance reports for each individual floor air distribution system and each ventilation system in accordance with the Subcontractor Scheduling Procedures in Section 23 00 20 titled "HVAC Scope of Work".
- I. A pre-construction balancing meeting with the Subcontractor and the Owner approved air and water balance Subcontractor(s) shall be conducted prior to the start of the balancing procedure to review the specifications, equipment schedules and submittals, discuss expectations, discuss any idiosyncrasies with the installed system, point out any observed system issues, and discuss intended sequences of operation as defined in Division 25. The pre-construction balancing meeting shall be conducted at least four (4) weeks prior to the start of any balancing procedures.

**3.3 TESTING, BALANCING AND ADJUSTING OF MECHANICAL SYSTEMS**

- A. Vibration Testing:
1. Field vibration and alignment measurements shall be taken on all water pumps, water chilling units, fans, and air handling units driven by a motor over 20 HP which appear in the judgment of the Engineer to have vibration, which exceeds the maximum vibration specified hereinafter. Readings shall include shaft alignment, equipment vibration, bearing housing vibration, foundation vibration, building structure vibration and other tests as directed by the Engineer.
  2. Readings will be made using portable IRD (or approved equal) equipment capable of filtering out various unwanted frequencies and standard reporting forms. Maximum vibration at any point listed above or specified shall not exceed 2 mils on centrifugal fan air handling units and individual fans, and 2 mils on pumps unless otherwise specified. Equipment manufacturers shall certify in writing that the field readings, which do not exceed the maximum specified, are acceptable to them. See Sections, 23 73 23 titled "Custom Factory-Built Air Handling Units", and 23 73 63 titled "Custom Factory-Built Tri-Path Multi-Zone Air Handling Units" for additional testing requirements.
  3. Vibration and alignment readings shall be taken by an independent testing agency. Submit qualifications of the independent testing agency to the Engineer for review.
- B. Refrigeration Systems Testing:
1. Water chilling unit refrigeration systems shall be tested for refrigerant and air leaks at least two (2) times, approximately six (6) months after startup and at the end of the warranty period. The Subcontractor shall provide a letter to the Owner at substantial completion confirming approximate dates for the required leak testing. The Subcontractor shall certify the condition of each refrigeration system in writing after each test. Any leaks detected shall be properly sealed and the above test period repeated. Soap suds and Halide torch or electronic refrigerant detector shall be used for leak detection.
  2. Refrigerant and oil lost during warranty period shall be replaced at no additional cost to the Owner. See Division 1 and Section 23 00 10 for warranty period requirements.
- C. Sound Testing:
1. Sound level readings shall be taken at twelve (12) locations in the building as selected by the Acoustical Consultant. The readings shall be taken on an Octave Band Analyzer in a manner acceptable to the Acoustical Consultant. The Subcontractor shall submit test equipment data and reporting forms to the Engineer and the Acoustical Consultant for review in accordance with the Subcontractor Scheduling Procedures in Section 23 00 20 titled "HVAC Scope of Work".
  2. In order to reduce the ambient noise level, the readings shall be taken at night. All tests shall be performed in the presence of the Owner, Project Acoustical Consultant and/or the Engineer, if they so desire.
- D. Hydrostatic Pressure Testing: Before piping of various systems is insulated, furred in or otherwise covered, hydrostatic leak tests shall be conducted as specified below.
1. Vents shall be provided at all high points of the piping system in the position, in which the test is to be conducted to purge air pockets while the component or systems is filling. Venting during the filling of the system may be provided by the loosening of flanges having a minimum of four bolts or by the use of equipment vents.
  2. Liquid for each hydrostatic test of piping (other than domestic water piping) shall be water and Nalco 2572 or approved equal corrosion inhibitor mixed to a ratio of fifty (50) gallons to 10,000 gallons of water, or a higher concentration if recommended by the chemical manufacturer or chemical treatment subcontractor. The entire testing process shall be monitored by the chemical treatment manufacturer and a written report issued to the Engineer and Owner two weeks after completion of the Subcontractor's hydrostatic testing. At least sixty (60) days prior to the start of hydrostatic leak testing a 2' long length of the typical piping installed on the Project shall be sent by the Mechanical Subcontractor to the Owner approved chemical subcontractor and chemical manufacturer to determine the composition of the internal pipe coating. Provide injection pumps, water meters and coupon racks to control and monitor the concentration. After leak testing and a sufficient time period to allow the interior of the piping to be chemically coated to prevent rust formation, the piping shall be drained until empty. Liquid for hydrostatic testing of domestic water systems shall be clean domestic water.
  3. The test equipment shall be examined before pressure is applied to ensure that it is tightly connected. Pressure gauges shall be calibrated before the testing. Gauges shall read in not more than 2 psig increments. All low pressure filling lines and all other items not subject to the test pressure shall be disconnected or isolated by valves or other suitable means.

4. The hydrostatic test pressure shall be 1-1/2 times the system working pressures listed in Section 23 05 07 titled "Design Conditions" except that the maximum test pressure shall be 500 psig. Equipment must be valved off or removed during the test if the pressure rating is lower than the test pressure. Equipment and piping shall be drained and protected anytime the ambient temperature is below freezing.
  5. The hydrostatic test pressure shall be continuously maintained for a minimum of two (2) hours after which each joint, connection, etc., shall be visually examined to verify there is no evidence of weeping or leakage. Each test shall be witnessed and acknowledged in writing by the General Contractor and/or Owner. The test may be witnessed by the Engineer if he so desires and pronounced satisfactory before pressure is removed or any water is drained off.
  6. The Subcontractor shall maintain a hydrostatic test log listing the system tested, portion tested, date of test, start time and pressure, finish time, pressure and test supervisor for each hydrostatic test. The hydrostatic test log shall be submitted to the Engineer and Owner for record prior to substantial completion of the Project.
- E. Diesel Fuel System Testing:
1. After fuel piping systems have been installed complete with fill, vent, suction and pressure piping, all tanks, valves, fittings and other accessories as specified herein, but before being covered or placed in use, the complete fuel piping system shall be tested for tightness by the Subcontractor. Tanks and piping, which are in a suction system shall be tested under pressure with dry compressed air at not less than three (3) psig nor more than five (5) psig. Pressure piping shall be pneumatically tested to one hundred and ten (110%) percent of the maximum anticipated working pressure of the system, but not less than 75 psig. Fill and vent pipes shall be pneumatically tested to the static head that would be imposed on the lowest level of piping if the fill and vent pipes were filled with oil, but not less than 10 psig. Tests shall be maintained for at least one (1) hour and may be witnessed by the Engineer's representative and the authorities having jurisdiction if they so desire. Test shall include a soaping of all joints and tank openings by the Subcontractor. No pressure loss will be acceptable.
  2. After initial tightness testing is successfully completed, all backfilling operations are complete and the entire system is installed including the engine(s), the system shall be retested for tightness as specified above to verify no damage was done during backfilling.
  3. After tightness testing is complete, fuel oil piping shall be blown clean with dry nitrogen and the system filled immediately with diesel fuel. All diesel fuel required for filling shall be provided by the Division 26 Subcontractor.
- F. Pump Alignment and Testing:
1. Pumps shall be tested to check impeller trim and operating characteristics. The following data shall be recorded and submitted to the Engineer for review. See Section 23 00 10 for requirements.
    - a. Flow at operating conditions where flow venturi or turbine type flow meters are installed in the system.
    - b. Shutoff pressure required to check impeller trim.
    - c. Discharge pressure at operating conditions.
    - d. Suction pressure at operating conditions.
    - e. Motor amperage and voltage on each phase at operating conditions.
    - f. Variable speed drive output frequency at operating conditions.
  2. Base mounted pumps shall be aligned after all piping connections are complete, installation and foundation bolts have been tightened, and bases have been grouted. Pumps and motors shall be aligned using a laser alignment tool or reverse dial indicator for offset and angular misalignment. Rough alignment may be accomplished using a straightedge and feeler gauge but will not be allowed for final alignment. Alignment tolerances shall, at a minimum comply with the specified coupling requirements, but shall not be more than 0.002" of offset misalignment in both the horizontal and vertical directions, and not more than 0.0005"/1 in. of angular (gap or face) misalignment. Record and submit coupling and alignment data on approved form for Engineer and Owner review. Refer to Section 23 21 23 for additional mounting and alignment requirements.
- G. Air Balance and Adjusting:
1. All air systems shall be air balanced by an AABC or NEBB certified balancing Subcontractor acceptable to the Owner and Engineer. The proposed Air Balancing Subcontractor shall be identified in the bidding proposal to the Owner.
  2. The Air Balancing Subcontractor shall visit the Project Site as often as necessary prior to the start of balancing procedures to verify that the duct systems have been properly installed complete with all grilles, dampers, ducts, coils, etc., and that the return air paths through walls, grilles, lighting fixtures

and slot diffusers are completely open and unobstructed. The Air Balancing Subcontractor shall also verify that adequate access to equipment and balancing devices has been provided and that the temporary plastic coverings on the lighting fixtures used for returning air through the lamp cavities have been re-moved. The building area being tested must be thoroughly cleaned by the General Contractor prior to testing to prevent dust and debris from entering the lighting fixtures, fan powered terminal units, ductwork, and other HVAC systems. The Air Balancing Subcontractor shall submit a written report to the Engineer and Owner within one (1) week after each visit.

3. The Air Balancing Subcontractor shall use a flow hood kit by Alnor Instrument Company or Shortridge Instruments, Inc. for the air balance. The flow kit shall be complete with flow hood tops specifically designed to accurately measure the air distribution devices specified for this Project. The flow hood's accuracy and the instrument calibration for measuring the air flow from the air distribution device specified for this Project shall be verified in an independent testing laboratory acceptable to the Owner and Engineer.
4. The Division 25 Subcontractor will assist the Division 23 Subcontractor in the startup and commissioning of the FPTU. The Division 25 Subcontractor will provide a hand held commissioning tool or equivalent laptop PC software and connecting cables to the Air Balancing Subcontractor for their use in performing the air balancing work. The Division 25 Subcontractor will train the Air Balancing Subcontractor in the proper use of hand held commissioning tool or laptop PC software.
5. Air systems shall be balanced with clean air handling unit filters or with the electronic air cleaner fully operational. Fan belt tension shall be checked prior to balancing and adjusted as required. Air handling units and fans with duct static pressure controls or automatic flow control systems shall have the controllers adjusted to maintain the specified pressure or flow prior to balancing. The Division 23 Subcontractor shall operate and maintain the washing cycles of the electronic air cleaner specified in Section 23 40 00 titled "Air Filtering" and furnish all water and washing fluids consumed during testing and air balancing.
6. Supply air systems installed in finished areas of the building (except for finished areas with inaccessible ceiling construction) shall be balanced and adjusted as follows:
  - a. After duct systems have been installed complete with all grilles, dampers, ducts, coils, automatic temperature controls and other items hereinafter specified, the Subcontractor shall make adjustments as required to deliver the volume of air at each interior and perimeter air outlet within ten (10%) percent of design flow as shown on the Drawings with design cold duct temperatures.
  - b. The balanced position of the balancing dampers shall be permanently marked on the duct or insulation. After the finished area is occupied, the air volumes shall be readjusted if required to properly balance the cooling and heating loads throughout the conditioned areas.
  - c. Air outlets shall be adjusted and balanced with the vertical or horizontal air pattern and flow direction as specified or as shown on the Drawings.
7. Supply air systems installed in finished areas with inaccessible ceiling construction, such as main lobby areas, shall be balanced and adjusted as follows:
  - a. After duct systems have been installed complete with all dampers, ducts, coils and other items hereinafter specified, except for final connection to grille or air outlet and prior to inaccessible ceiling installation, the Subcontractor shall make adjustments, as required, to deliver the volume of air at each interior and perimeter air tap proportionally within ten (10%) percent of design flow as shown on the Drawings.
  - b. After each duct system has been adjusted the Subcontractor shall securely lock each manual damper, splitter, spin-in damper, etc., with sheet metal screws prior to installation of ceiling.
  - c. The Subcontractor shall submit balancing reports to the Engineer for review and comment as specified hereinafter, prior to the installation of the inaccessible ceiling. No duct system shall be concealed prior to the Subcontractor being in receipt of a "Final Reviewed" air balance report for the system.
  - d. After ceiling installation, each air outlet shall be installed with air patterns as shown on the Drawings. Final air balance adjustment shall be made by increasing or decreasing the air handling unit fan rpm.
8. Supply air systems installed in unfinished tenant areas of the building shall be balanced as follows:
  - a. After duct systems have been installed complete with all grilles, dampers, ducts, coils, automatic temperature controls and other items hereinafter specified, except the duct taps serving the air diffusers in the interior zones, the Subcontractor shall make all adjustments, as required to deliver the volumes of air within ten (10%) percent of air handling unit or fan powered terminal design flow as shown on the Drawings or as indicated in the "Schedule of Capacities" in the Contract Documents. The fan powered terminals and perimeter slots shall be balanced by the Subcontractor to deliver the volumes of air within ten (10%) percent of the outlet design flow as indicated on the Drawings using the procedure hereinafter. Sufficient temporary openings are to be

- provided in the interior zone duct systems in order that the interior zone air fan powered terminal unit discharge volumes can be adjusted. The interior ductwork end caps shall be removed and replaced by the Subcontractor.
- b. The following procedures shall be followed for the balancing and commissioning of series fan powered terminal units with mismatched airflows (fan CFM greater than primary airflow) and dynamically reset fan volume control with ECM fan motors:
- 1) Shut down the terminal unit fan and remove the construction filter from the induction port return air inlet.
  - 2) The fan powered terminal unit manufacturer shall provide an algorithm to the Division 25 Subcontractor that will allow the Division 25 unitary controller (UC) to directly reset the terminal unit fan air flow rate.
  - 3) The Division 25 Subcontractor shall field program the design set points as indicated in the Contract Document schedules for 1) maximum cooling fan airflow, 2) minimum fan airflow, 3) maximum heating fan airflow, 4) maximum primary valve airflow, and 5) minimum primary valve airflow. The Division 25 UC shall constantly reset the primary and fan airflows based on the room demand calculation used in the UC to reset the primary air damper. The primary air damper shall modulate between the maximum primary cooling airflow and the minimum primary airflow as scheduled in the Contract Documents. The fan and ECM motor assembly shall modulate the maximum fan cooling airflow to the minimum fan airflow and then to the maximum heating airflow as the terminal unit cycles from full cooling to full heating, as scheduled in the Contract Documents.
  - 4) Airflow settings shall be reported from the BMCS in cubic feet per minute or liters per second as scheduled, not as a percentage of the set points.
  - 5) Prior to starting the terminal unit the fan controller provided with the terminal unit shall be verified to be in the automatic mode.
  - 6) The primary air handling unit air system shall be operating with minimum static pressure at the fan powered terminal unit inlets. The flow cross devices on the fan powered terminal shall be checked for proper calibration. The primary air handling unit air supply system shall be set to maintain approximately 0.25" w.g. at the most remote fan powered terminal unit when that unit is at full flow design conditions.
  - 7) The terminal unit shall be started and adjusted through the Division 25 BMCS to the maximum cooling fan airflow rate. Fan airflow shall be verified by measuring the fan controller DC voltage signal. The DC voltage shall be compared to the terminal unit airflow chart provided by the terminal unit manufacturer to determine the fan airflow rate. The Air Balance Subcontractor shall not readjust the fan speed.
  - 8) Set the fan air flow rate equal to the maximum primary air valve setpoint. After the fan is set to the specified airflow, the primary air damper shall be adjusted until no air is induced or expelled at the induction port of the terminal unit. The induced air opening shall be covered with a temporary cover during this test except for a 3 inch diameter hole in the center of a test cover. When there is no airflow either in or out of the induction port through the 3 inch test opening, the primary airflow and fan airflow shall be considered equal. At this point the "K" factor for the primary air valve shall be calculated, recorded, and set.
  - 9) Fan airflow rates for minimum cooling airflow, maximum heating airflow, and primary air valve minimum airflow shall be adjusted and set using the procedure described above. Recheck and confirm the "K" factor established in setting the maximum cooling airflow described above has not changed.
  - 10) Hot water heating coil operation shall be checked by verifying the hot water valve actuator is operational from the full closed to full open positions when signaled by the Division 25 unitary controller output.
  - 11) Balancing hoods shall not be used to verify diffuser airflow rates. Balancing hoods shall be used only to confirm a proportional air balance for diffusers attached to an individual fan powered terminal unit. Adjust manual balancing dampers on each diffuser as necessary to achieve a proportional balance of the diffusers with a maximum difference of ten (10%) percent between the diffuser design CFM and the reading on each diffuser.
  - 12) Replace fan powered terminal unit inlet air filters with clean set supplied by the Division 23 Subcontractor.
  - 13) Report all deficiencies to the Division 23 Subcontractor and to the Engineer.
  - 14) Reset room sensor to the design setpoint.
- c. The final balanced position of manual balancing dampers such as in each air handling unit zone duct shall be permanently marked on the ductwork or insulation by the Air Balancing Subcontractor.
9. Supply air systems in raised floor areas shall be balanced and adjusted as follows:

- a. Downflow Discharge Computer Room Air Handling Units: After computer room air handling units, ductwork, grilles, registers, dampers, fans, automatic temperature controls and other items specified hereinafter have been installed, the Division 23 Subcontractor shall make adjustments as required to deliver the volume of air at each floor supply register within ten (10%) percent of design flow as shown on the Drawings with the design cold duct temperatures. Systems shall be balanced with all computer room air handling units and local ventilation fans in their normal operating mode.
  - b. Custom Factory-Built Tri-Path Multi-Zone Air Handling Units: After tri-path multi-zone units, floor grilles, raised floor, perimeter zone ductwork, outside air economizer ductwork, automatic temperature controls and other items specified hereinafter have been installed, the Division 23 Subcontractor shall make adjustments as required to deliver the volume of air specified within ten percent (10%) of design flow as shown on the drawings. Down-flow section of each unit shall be balanced with the transfer deck air flow set at minimum flow. Multi-zone section of each unit shall be balanced with transfer deck air flow set at maximum flow. Economizer dampers shall be set at maximum outside air flow. Return air damper shall be set at minimum return air flow. Each perimeter zone shall be balanced at 100% of design flow. Each slot diffuser shall be balanced to within ten percent (10%) of design flow as shown on the drawings. Air flow in each perimeter zone shall be reset through the control system to 50% of design flow. Perimeter slots shall be re-checked at the 50% flow rate to verify balance remains proportional.
10. After all pressurization, ventilation, garage supply and exhaust systems, and exhaust air systems have been installed complete with all duct, grilles, louvers, dampers, fans and other items as hereinafter specified, the Subcontractor shall make adjustments, as required to deliver the volumes of air or differential static pressures in the case of the pressurization fans, at each air inlet and/or outlet within ten (10%) percent of design flow.
- a. All tests shall be performed as specified herein and in accordance with the procedures and test criteria established by the local authorities having jurisdiction. The mechanical, fire protection, fire alarm, electrical, Division 25 Subcontractor and the Contractor shall be present and shall participate during the entire testing procedures. The Mechanical Subcontractor shall furnish smoke bombs when required.
  - b. The Subcontractor shall verify and record that the quantity of air indicated on the Drawings is exhausted at the smoke removal inlet and shall verify and record the quantity of air flowing through the exhaust fan. Tests shall demonstrate the proper sequence of the fire safety ventilation systems, the activation of the smoke detection system, smoke exhaust system, and makeup air from the stairwell systems. The smoke management systems installed in this Project shall be performance tested in accordance with the requirements of the authorities having jurisdiction and the Fire Department.
  - c. The demonstration tests shall be conducted and repeated until they are accepted and approved by the authorities having jurisdiction. The Mechanical Subcontractor shall include all costs associated with the required demonstration tests, including smoke bombs, instrumentation, etc.
  - d. Coordinate test procedures for compliance with the fire life safety smoke control report dated December 16<sup>th</sup>, 2013..
  - e. The stairway pressurization systems shall be tested after the stairway shaftway has been checked for leaks, cracks, door seal function, etc. Smoke bombs shall be activated in the stairway to verify tightness of enclosure. The maximum differential pressure at any point in the stairway between the stairway and the building shall not exceed 0.20" w.g. with all doors closed. The minimum differential pressure at any point between the stairway and the building shall not be less than 0.15" w.g. with all doors closed. The pressurization system shall provide a minimum air velocity of 300 feet per minute through the open door farthest from the pressurization source, and one (1) other open door at the center of the shaft.
  - f. The Building Lobby Exhaust System shall be performance tested by demonstration of the proper sequences of the fire safety ventilation system, automatic opening of the operable windows, etc., by placing smoke bombs in the Lobby and Atrium and verifying the air flow through the smoke exhaust fans. Tests shall demonstrate the activation of the smoke detection system, smoke exhaust system and makeup air system.
  - g. At least one (1) Typical Floor and one (1) Garage Floor in each elevator riser with smoke exhaust systems shall be performance tested by demonstration of the proper sequences of the fire safety ventilation system, automatic damper operation system and other functions involved. Test shall demonstrate the activation of the smoke detection system, smoke exhaust system and the makeup air systems.
  - h. The elevator pressurization systems shall be tested after the elevator shafts have been checked for leaks, cracks, etc. With all elevator banks served by a system in operation simultaneously, the minimum differential pressure between the elevator shaft and the building shall not be less than

0.10" w.g. at any point in the elevator shaft. With each elevator bank in each system operating individually, the pressurization system shall not inhibit the operation of the elevators in any way. Under this condition, the operation of each car shall be demonstrated at each stop.

11. All balancing must be accomplished with diffuser air patterns as indicated on the Contract Drawings and/or Tenant Improvement Drawings.
12. The Subcontractor shall submit detailed balancing and performance testing procedures, recording forms and test equipment for all testing specified herein for the Engineer's review in accordance with the Subcontractor Scheduling Procedures in Section 23 00 20 titled "HVAC Scope of Work".
13. Submit six (6) copies of complete reports to the Engineer for review and comment, and send two (2) copies of the reports to the Owner.

H. Water Balancing and Adjusting:

1. All water systems shall be balanced by an AABC certified balancing Subcontractor acceptable to the Owner and Engineer. The proposed Water Balancing Subcontractor shall be identified in the bidding proposal to the Owner.
2. After piping systems have been installed complete with all pumps, piping, valves, coils and other items as herein specified, the Subcontractor shall make adjustments as required to deliver the water volumes at each coil and piece of equipment to within five (5%) percent of design flow as shown on the Drawings or as indicated in the "Schedule of Capacities" in the Contract Documents or as required to properly balance the cooling load or process load throughout the conditioned areas. Adjustments in water volumes shall be made in a manner satisfactory to the Engineer. The Subcontractor shall submit detailed balancing procedure and recording forms for the Engineer's review in accordance with the Subcontractor Scheduling Procedures in Section 23 00 20 titled "HVAC Scope of Work". At a minimum, the Subcontractor's balancing procedure shall contain the following steps:
  - a. Review entire piping system to confirm location and installation of all flow control devices, balancing valves, Pete's plugs, Schrader valves, flow meters, etc., as necessary to perform a complete water balance. Subcontractor shall report all deficiencies to the Owner and Engineer for correction prior to starting balance procedure.
  - b. All manual valves, balancing valves, and control valves used for normal operation shall be positioned to 100% open. Valves intended to remain closed during normal operation, such as equipment by-pass valves and the by-pass ports on 3-way control valves shall be positioned 100% closed. Valves intended to modulate during normal operation, such as differential pressure by-pass valves and cooling tower by-pass valves, shall be manual positioned to 100% closed for the balancing procedure.
  - c. Verify entire piping system has been filled, cleaned, and treated, all automatic air vents are functional and venting properly, all manual air vents, all equipment vents, and blow-down drains have been purged to ensure all air pockets have been vented.
  - d. Water systems shall be balanced with clean strainers and cartridge filtering elements in the bypass filters.
  - e. All system pumps associated with the water system being balanced shall be running in normal operation mode to provide design water flow. Stand-by pumps shall be off. Pumps controlled by variable speed drives (VSD) shall be manual controlled to prevent automatic pump speed changes during the balancing process. Initial differential pressure for variable speed pump systems shall be manual set at the VSD to the specified set-point in Section 25 90 00.
  - f. Preliminary water balance shall be conducted by adjusting return water shut-off/balancing valves starting with equipment nearest the pumps/central plant working to the most remote equipment.
  - g. Water flow shall be adjusted by measuring differential pressure across various system components with known flow and pressure drop characteristics, such as cooling and heating coils, heat exchangers, or control valves with a specific Cv value.
  - h. Each air handling unit with multiple coils shall have the flow through each coil balanced proportionally.
  - i. Water flow through components that have been adjusted may change as the balance procedure continues through the system due to the dynamic nature of each piping system. The Subcontractor shall repeat the procedure described hereinabove of re-checking water flow and re-adjusting balancing valves two or more times as necessary to meet the specified flow rates. The balance procedure shall be considered complete when design flow rates are met at all equipment locations with the lowest possible system differential pressure and pumping break horsepower.
  - j. The Subcontractor may find a system has insufficient pumping capacity to meet 100% of design flow at each piece of equipment (the sum of the scheduled equipment flow requirements exceeds the sum of the pump flow requirements). If this condition exists the Subcontractor shall perform a



- proportional balance of the system at each piece of equipment with the pumping system operating at 100% design flow.
- k. The Subcontractor may find a system has more pumping capacity than the sum of the scheduled equipment flow requirements. Pumps may be oversized to supply "future" loads. If this condition exists, the total system flow should be adjusted at the pumps with the associated pump VFD's so design flows at each piece of equipment can be achieved, but not exceeded, and balancing valves are positioned so as to not require excess differential pressure.
  - l. After all water flows are adjusted the Subcontractor shall lock and record the position of all memory-stops at the balanced position.
3. Submit six (6) copies of complete comprehensive bound reports of the performance testing of the systems to the Engineer for review and comments in accordance with the Subcontractor Scheduling Procedures in Section 23 00 20 titled "HVAC Scope of Work". Identify all data completely. Identify the manufacturer, size, type, location, room number and zone of each coil and piece of equipment reported. Give design and actual water flow. Give complete nameplate data for each piece of equipment reported. The mechanical systems will not be accepted until the required reports are received, reviewed and accepted.
- I. Final Water and Air Balance Readings:
    1. After water and air flow are balanced, and with the temperature controls set to produce design cooling, measure and record all data necessary to compile a complete report to demonstrate the acceptability of the various mechanical systems. Include at least the following data in the report:
      - a. Outside dry bulb and wet bulb temperature.
      - b. Inside dry bulb and wet bulb temperatures in six selected areas of the conditioned space, room or area selected by the Engineer.
      - c. Dry bulb temperatures of air entering and leaving all air handling unit coils.
      - d. Temperature of water entering and leaving each air handling unit coil.
      - e. Temperatures at all thermometer well locations.
      - f. Temperature of water entering and leaving each water chilling unit condenser and evaporator.
      - g. Temperature of water entering and leaving each heat exchanger.
      - h. Suction and discharge pressures and shutoff head of each water pump.
    2. With controls set for design heating, repeat procedure specified in the immediately preceding subparagraph.
    3. The balanced position of each controlling valve shall be permanently marked on the pipe or insulation.
    4. Forward six (6) copies of these readings to the Architect/Engineer for review and comment and send two (2) copies of the readings to the Owner in accordance with the Subcontractor Scheduling Procedures in Section 23 00 20 titled "HVAC Scope of Work".
  - J. The balancing Subcontractor shall participate in the Division 25 BMCS calibration verification procedure as approved by the Commissioning Agent. The balancing Subcontractor shall provide measured sensor values from his testing instruments to the Division 25 BMCS Subcontractor for comparison to the specified values and tolerances. All device readings for sensors such as differential pressure sensors and airflow rate transmitters shall be recorded in the final water and air balance report. Refer to Division 25 for additional information.
  - K. The Division 23 Subcontractor shall demonstrate to the Engineer and the Owner, prior to acceptance by the Owner, that all systems and/or equipment have been balanced and adjusted properly and that the systems and/or equipment are in compliance with the Contract Documents.

**END OF SECTION**