SECTION 01662 COMMISSIONING

PART 1 - GENERAL

1.1 DESCRIPTION

A. This Section defines the responsibilities of the Contractor to perform and document the commissioning of systems installed. All commissioning work shall be performed by the Contractor and witnessed by the University’s Representative.

1.2 RELATED WORK AND DOCUMENTS

A. Section 01334 Shop Drawings, Product Data and Samples
B. Section 01660 Systems and Equipment Start-Up, Testing and Adjustment
C. Section 01664 Demonstration and Training.
D. Section 01830 Operation and Maintenance.
E. Division 2 Site Construction. Individual sections stipulate specific installation and start-up requirements for site utilities.
F. Division 11 Equipment (if used).
G. Division 13 Special Construction (if used).
H. Division 14 Conveying Systems Sections: Individual sections stipulate specific installation and start-up requirements for Elevators (if used).
I. Division 15 Mechanical.

MAKE SURE THAT THE DDC/EMS COMMISSIONING SECTION IS NUMBERED 15959 IN THE SPECIFICATION

J. Section 15959 DDC/EMS Commissioning.
K. Division 16 Electrical.

1.3 DEFINITIONS AND ABBREVIATIONS

A. Refer to Section 01660 Systems and Equipment Start-Up, Testing and Adjustment

1.4 CONTRACTOR RESPONSIBILITIES

A. Construction

1. Schedule and coordinate Commissioning efforts required by appropriate subcontractors and vendors.
2. Certify that systems have been correctly installed and are operating per Contract Documents.
3. Prepare and submit draft Equipment Performance Tests (EPT), Functional Performance Tests (FPT) and Operational Tests (OT), as defined below, for all installed systems.

B. Testing

1. Conduct Equipment Performance Testing, System Functional Performance Testing, and System Operational Testing with University’s Representative present:
   a. Simulate design conditions, measure and record equipment and system performances.
   b. Provide all necessary metering and instrumentation to perform Equipment and System FPT.
   c. Manipulate control systems to facilitate verification and performance testing.
   d. Simulate various modes of operation including failure mode simulations, make corrections to meet contract requirement and record the result.

2. Correct any work found not in accordance with Contract Documents.

C. Documentation to be Submitted for Review and Approval Prior to Testing

1. Documentation Plans:
   a. The Contractor shall develop a record keeping system to document compliance with the requirements of this Section.

2. Equipment and system documentation shall include:
   a. Date of test.
   b. Equipment number or system name.
   c. Test objectives.
   d. Test results.
   e. Test instruments employed for the test.
   f. Signature spaces for the University's Representative and the Contractor.

   A separate section in the commissioning documents shall be established for testing each system and item of equipment. These files shall include the following information as a minimum:
   (1) Factory performance tests.
   (2) Field calibration tests: Each of these tests is required even though not specifically noted in detailed specification section.
   (3) Field pressure tests: Each of these tests is required even though not specifically noted in detailed specification section.
   (4) Equipment Performance Tests, Functional Performance Tests, and Operational Tests for project equipment and systems.

3. Test Plans:
   a. The Contractor shall develop test plans to include sequential testing of each item of equipment and system installed. Each test plan shall be specific to the item of equipment or system to be tested. Test plans shall identify by specific equipment or tag number each device or control station to be manipulated or observed during the test procedure and the specific results to be observed or obtained. Test plans shall also be
specific as to support systems required to complete the test work, temporary systems required during the test work, subcontractors' and manufacturers' representatives to be present and expected test duration. As a minimum, the test plans shall include the following features:

1. **Equipment Performance testing** of each individual item of mechanical, electrical, and instrumentation equipment as part of a system. Equipment performance tests shall be designed to demonstrate the satisfactory functioning of individual pieces of equipment. This includes procedures to show all control and electrical circuits are correctly identified and connected to the proper device.

2. **Functional Performance tests** designed to simulate, as closely as possible, operating conditions described in the Contract Documents. Systems tests demonstrate the satisfactory performance of equipment as part of a total system. Each FPT must list what other systems must be fully functioning correctly in order to provide required performance. An FPT cannot take place if any of its prerequisite systems is not on and operating correctly. Part of the FPT is establishing and listing trended points that can be used to show continued system performance.

3. **Operational testing** shall demonstrate satisfactory performance over a period of time of the various modes of operation likely to occur during occupancy. In addition, it will confirm the satisfactory recovery of a systems from such failures as power outages, etc., including emergency generator operation. Operational tests also must include tests that prove the correct performance of all systems affected by the Fire Alarm system. Trends will be used to establish histories of satisfactory system performance.

4. **Recommissioning testing information** for all systems at a future date. Recommissioning information shall include specific procedures to retest specific systems as well as directions to remedy systems not performing to meet the design intent of the project documents. Examples might be tests to shutdown equipment in emergency conditions or tests to demonstrate correct pressurization control of a system to a commanded setpoint.

b. Test plans shall contain a complete description of the procedures to be employed to achieve the desired test environment, and provide documentation of the calibration of the required sensors and instruments needed to prove correct operation and accuracy of utilized devices.

4. **Testing Schedule:**

a. The Contractor shall produce a testing schedule setting forth the sequence for performing the test work. The schedule shall be in conformance with Section 01329 Contract Schedules and shall detail the equipment and systems to be tested, and shall be coordinated with the
Contractor's construction schedule. The test schedule shall be submitted no later than 28 days in advance of the date testing is to begin. The schedule shall show the projected start dates, durations of each test, and the projected end dates.

b. The University’s Representative will not witness any testing work for the purpose of acceptance until the Contractor has submitted a schedule to which the University’s Representative takes no exception. The test schedule shall be updated weekly, showing actual dates of test work, indicating systems and equipment testing completed satisfactorily and meeting requirements.

5. On-site Commissioning Information Catalog Rack:
a. The Contractor shall supply and maintain on the construction site a sectional catalog rack whose ringed removable sections contain the approved commissioning testing requirements for individual systems. Each section will have its own 3-ring locking mechanism which can be removed independently so that it may be taken into the field for reference and for recording progress and test results. Sections may hold such information for several systems, but an index on the rack must list the systems in each section. Each system with the section must have the testing procedures of the EPT, FPT, and OT of that system. This binder will serve as the official repository for recording the commissioning progress on each system, and, as tests are performed, the results of these tests will be noted and signed off if satisfactory. This rack is to remain on site for the duration of the project, and sections are to be returned to the rack so that, at the end of each day, the rack has all of its sections intact.

1.5 EQUIPMENT TESTS, FUNCTIONAL PERFORMANCE TESTS AND OPERATIONAL TEST

A. Procedures for the Equipment Performance Test, Functional Performance Test and Operational Test for each piece of equipment and system shall be submitted to the University’s Representative for approval prior to execution of the tests. Contractor shall design these tests to include all criteria needed to ensure satisfactory equipment and system performance.

B. Tests shall be developed in a step-by-step format with space provisions for recording pertinent data and test results.

C. Approved Test Procedures for all systems shall be produced for review by the University’s Representative as a condition precedent to progress payments in excess of 75 percent of the Contract Sum.

D. FPT Checklists shall be formatted and developed similar to the sample checklist.

E. Refer to Division 15 Mechanical and Division 16 Electrical for additional commissioning requirements.

PART 2 - PRODUCTS

2.1 INSTRUMENTATION

A. Contractor shall provide all instrumentation required to verify performance of systems.
B. All equipment used for testing and calibration shall be National Institute of Standards and Technology/National Bureau of Standards (NIST/NBS) traceable and calibrated within the current 12 month period. Certificates of calibration shall be made available for verification by University’s Representative during testing.

PART 3 - EXECUTION

3.1 GENERAL

A. Tests indicated herein are general functional testing requirements that apply to typical equipment, systems and sub-systems. Contractor shall prepare itemized testing plans and procedures for each system that will:
   1. Incorporate the tests and procedures that meet the general requirements of Contract Documents.
   2. Serve to document and record the testing procedures and the results of the tests.
   3. Refer to the sample functional performance test following this section for formatting.
   4. In addition to items identified below, refer to Divisions 15 Mechanical and 16 Electrical for additional testing and commissioning requirements.

3.2 COORDINATION BETWEEN TESTING PARTIES

A. Factory Start Ups: For many systems and equipment, factory start-ups are specified for testing during functional performance testing. Contractor shall notify the University’s Representative when factory start-ups are scheduled. Aspects of Equipment Performance Testing and Functional Performance Testing accomplished during the factory start-up may be accomplished and approved if they meet the intent of the EPT and FPT.

B. Independent Testing Agencies: For systems where independent testing agencies are specified, much of the testing performed by these independent agencies will cover aspects required in the Start-ups and Functional Performance Tests.

3.3 PREREQUISITES

A. All equipment, components and devices requiring an EPT, FPT and OT must be started, and this start-up must be documented. This includes completion of the checklists, pressure testing of equipment, duct, pipe, etc., flushing and cleaning of applicable systems, completed labeling and identification, completed insulation of applicable systems.

B. Unless specifically agreed to in writing by the University’s Representative, all support systems shall be complete prior to FPT. An air handler for instance will require that:
   1. The electrical system serving it is completed and tested.
   2. The hydronic systems serving it have been balanced and functionally tested.
   3. Balancing has been accomplished for both air and water.
   4. The control systems have been started and calibrated.
3.4 COMMON ELEMENTS FOR ALL SYSTEMS

A. Record test results and testing progress in the job site Commissioning Information Rack. Validate that all required documentation within this rack has been submitted and approved in conformance with project requirements.

B. Contractor shall submit the start-up documentation prior to testing.

C. Contractor shall demonstrate that access is sufficient to perform required maintenance.

D. Trends on each control system are to be created, and be actively recording and storing data at the latest after the FPT has been completed successfully.

E. As part of the Operational Testing, all dynamic systems powered by electricity shall be tested to simulate a power outage to ensure proper sequencing. Those systems on emergency power shall be tested on all sources. Recovery from power outage conditions will also be observed for proper return to regular system operation.

F. Sequencing Verification: All modes of operation and actions shall be verified for equipment and system samples.

G. All adjusted, balanced, controlled systems shall be assessed to determine the optimal setting for the system as applicable. The optimal settings shall be determined to establish reliable, efficient, safe and stable operation. Electrical settings shall conform to Power System Study.


FROM HERE DOWN, PM OR CONSULTANT SHOULD EDIT TO BE PROJECT SPECIFIC.

3.5 CONVEYING SYSTEMS

A. Hydraulic Elevators

1. Test: Upon completion of elevator, Contractor shall provide all necessary instruments, weights and personnel to conduct the D. I. S. inspections and the following performance tests, which shall be witnessed by the University’s Representative. The Contractor shall submit a complete report describing the results or the tests.
   a. Full load test.
   b. 1-hour heat and run test with fill load in car. Car shall run for 30 minutes with all stops UP and DOWN and then for 30 minutes between terminal floors. The time interval between each stop and start shall be 10 seconds.
   c. Stop car at each floor in each direction

2. Performance and leveling tests shall be made before and after heat and run test, at full load and 50 percent weight in car.

3. Check and verify operation of all safety features, particularly:
   a. Door pressure and impact.
   b. Fire service.
4. Tests to ascertain the starting and running currents, Voltage and speed under the conditions of loading specified in the preceding items.
5. Tests to demonstrate the settings and effectiveness, under various conditions, of all overload and overtime protective devices.
6. Demonstrate floor level accuracy of +/- 3/8 inch through all ranges of loading; from empty car to contract load and from cold start to regular operating temperature.

B. Traction Elevators

1. Test: Upon completion of elevator, Contractor shall provide all necessary instruments, weights and personnel to conduct the D. I. S. inspections and the following performance tests, which shall be witnessed by the University’s Representative. The Contractor shall submit a complete report describing the results of the tests.
   a. Full load safety and buffer tests.
   b. 1-hour heat and run test with full load in car. Car shall run for 30 minutes with all stops UP and DOWN and then for 30 minutes between terminal floors. The time interval between each stop and start shall be 10 seconds.
   c. Stop Car at each floor in each direction.
2. Provide well-shielded thermometers for hoist motor and generator and verify that temperatures do not exceed 50 degrees Centigrade above ambient.
3. Performance and leveling tests shall be made before and after heat and run test, at full load and balance weight in car.
4. Overload test with 125 percent of load in car per ANSI Code.
5. Check and verify operation of all safety features, Particularly:
   a. Fire service.
   b. Door pressure and impact.
6. Tests to prove that the elevator power control circuits will maintain a pollution free feedback to the supply feeders, under all conditions of loading.
7. Tests to ascertain the starting and running currents, voltage and speed under the conditions of loading specified in the preceding items.
8. Tests to demonstrate the settings and effectiveness, under various conditions, of all overload and overtime protective devices.
9. Demonstrate floor level accuracy of +/- 1/4 inch through all ranges of loading; from empty car to contract load and from cold start to regular operating temperature.

3.6 HEATING VENTILATION AIR CONDITIONING (HVAC) PUMPS

A. Contractor shall demonstrate that strainers are clean.

B. Pumps shall be manually started individually. Pressure differential, kilo-watt (KW) (or slip on the motor), and flow shall be checked at shut-off, wide open, and balanced (or controlled) condition. Contractor shall simulate design condition and record pump performance. Identify the operating parameters on system curve (similar to test and balance). The reading from the instrumentation provided with
the pump (thermometers and pressure gages and flow meters as applicable) can be used to validate the pump performance. Pump functional test can be obtained from Balancing Contractor.

C. For pumps designed with automatic starting of back up pump on primary pump failure, enable automatic controls, stop primary pump and validate that standby is operating. Perform this test on both pumps.

D. For variable speed pumps, manipulate control valves to change flow conditions and observe control response. Ensure stable control response to step change in flow conditions. Check for the applicable acceleration and deceleration of the pumps. Manually ramp pump speed from minimum and maximum to ensure stable operation of pumps and record any critical frequencies. Record representative part load output from the drive (using Variable Frequency Drive (VFD) read out). Check calibration of control input. Check drive bypass operation if applicable.

E. Check, verify and record all interface points with building energy management system, including all alarms.

F. Verify and record location of end of line differential pressure and final setting.

3.7 HYDRONIC SYSTEMS

A. Check system make up and pressurization. Record optimal settings. Ensure air is removed by bleeding the sample rate of coils or high points. Ensure expansion tanks are properly charged (if any).

B. Blow off selected strainers to ensure the system is flushed and clean.

C. Refer to Testing and Balancing verification.

3.8 BUILDING CHW LOOP

A. Open building control valve, measure and record flow to the building and the pressure differential.

B. Command the building valve to close and ensure adequate shut off.

C. In both the coupled and decoupled modes, Enable automatic control of the building loop and trend performance. Make at least one step change in the loop setpoint during the trend period.

D. Refer to HVAC Systems Pumps for pump testing. Additionally, with a fixed setpoint on the building valve control loop, establish a trend on the pump control loop. Observe normal control function. Introduce 1 setpoint step change and observe response.

E. Change setpoint to cause a change between coupled mode and decoupled mode and back. Observe system performance. Trend all values and print trend for documentation.

F. Check and verify all interface points with building energy management system.
3.9 COOLING TOWER WATER SYSTEM
A. Verify the tower enable and disable sequences.
B. Verify proper stage up and stage down of the towers by the control system as load is varied. Load can be varied by manipulating valves, starting and stopping hot water terminals and changing the staging control parameters.
C. Verify proof and enunciation of individual towers upon failure. Verify that tower requests are removed appropriately and the next tower in rotation is energized.
D. Check and record the Net Positive Suction Head (NPSH) on the pumps throughout various modes of operation.
E. Check the sump level control to ensure air is not drawn into the system and that no air pockets exist in the suction piping.
F. Check fan vibration, confirm vibration switches operation.
G. Refer to HVAC pump FPT and OT for additional testing.
H. Check and verify all interface points with building energy management system.

3.10 STEAM TO HOT WATER HEAT EXCHANGER
A. Contractor shall start and warm-up the converter.
B. Record Hot water system pressurization and ensure that the air has been removed and the system is under positive pressure at all points in the system.
C. Verify proper steam pressure upstream of valve and proper water flow through converter.
D. Verify that steam valve(s) modulates and stages to maintain water temperature. Verify proper sequencing of valves where applicable. Observe control response to varying loads and ensure stable response. Loads shall be verified by Contractor by starting and stopping air handling units or by other suitable means.
E. Set valves and flow for full heating and verify maximum heating capacity.
F. Verify location of trap meets manufacturer requirements and traps operating properly.
G. Verify proper operation of makeup water system, including chemical treatment.

3.11 FAN COIL UNIT
A. Verify automatic start and stop of fan.
B. Start heating and cooling system, manipulate control device to obtain maximum cooling and heating. Measure air and water inlets and outlet temperatures to determine capacity.
C. Cause all applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.
D. Check calibration of control devices and for stable control response.
E. Test and verify all interface control points with building energy management system (EMS).

3.12 AIR HANDLING UNIT (AHU)

A. Verify automatic start and stop of fan and open and close of outdoor air damper utilizing building EMS.

B. Start heating and cooling system, manipulate control device to obtain maximum cooling and heating. Measure air and water inlet and outlet temperatures and pressures to determine capacity.

C. Simulate design condition and record AHU performance (air and water), identify operating parameters on system curve (similar to test and balancing).

D. Cause all applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.

E. Check calibration of control devices for stable control response and component performance including chilled water coils, hot water coils, humidifiers, economizer cycles, etc. Ensure proper coordination of control and tune the control loops to stabilize control and avoid energy wastes.

F. Check for free and adequate flow of AHU condensate. Check that condensate line is piped to a suitable drain.

G. For variable speed fans, manipulate air terminal units to change flow conditions and observe control response. Ensure stable control response to step change in flow conditions. Manually ramp fan speed from minimum to maximum to ensure stable operation of fans. Record representative part load output from the drive. Check calibration of control input.

H. Ensure minimum required ventilation rates are maintained across the full range of control where applicable.

I. Test all interfaces with the fire alarm system and all smoke control sequences.

J. Verify interlocks with exhaust fans where applicable.

K. Test proof alarming where applicable.

L. Test operation of applicable safeties including freeze stats, high and low static devices, smoke detection, etc. Check AHU component status in each event.

M. Check system status and operation in the Off, Unoccupied, and Occupied Mode of operation. Validate proper start up and shut down sequences.

N. Test and verify all interfaces with building EMS.

O. For AHU with multiple supply motors or lead/lag standby AHUs, fail each motor or unit in sequence, ensure proper start-up of the secondary unit. Record results including alarms. Correct deficiencies and identify operational strategies.

P. After 24-hour operation, recheck belt tension and alignment.
3.13 FAN AND AIR SYSTEM

A. Verify start and stop control sequences.
B. Simulate design condition and record AHU performance (air and water), identify operating parameters on system curve (similar to test and balancing).
C. Cause all applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.
D. For variable speed fans, manipulate air terminal units to change flow conditions and observe control response. Ensure stable control response to step change in flow conditions. Manually ramp fan speed from minimum and maximum to ensure stable operation of fans. Record representative part load output from the drive. Check calibration of control input.
E. Verify interlocks with other exhaust fans where applicable.
F. Test all interfaces with the fire alarm system and all smoke control sequences.
G. Test proof alarming where applicable. Simulate failures of fans and ensure proper start up of back up fans. Record results, correct deficiencies and develop operational strategies.
H. Test operation of applicable safeties including freeze stats, high and low static devices, smoke detection.
I. Test and verify all interface points with building EMS.
J. Verify start/stop control sequences at motor control.
K. Simulate design condition and record fan performance. Identify operating parameters on system curve (similar to test and balancing).
L. After 24-hour operation, recheck belt tension and alignment.

3.14 HVAC (NON LAB) VARIABLE AIR VOLUME (VAV) AIR TERMINAL

A. Check the calibration of zone temperature sensors.
B. Set boxes for both minimum and maximum flow (typically by setting the space temperature setpoint up and down) and check the calibration of the flow settings.
C. Check the stability of the zone temperature control loop for the damper and any associated heating devices by changing the space setpoints and observing the response.
D. Cause all applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.
E. Determine the optimal settings for the control parameters.
F. Simulate and test the unoccupied and emergency mode response of the box where applicable.
G. Check the capacity of the heating device including inlet and outlet water temperature where applicable.
3.15 LAB ZONE AIR FLOW TRACKING SYSTEM

A. Adjust the control parameters to obtain both minimum airflow and maximum zone air flow conditions. This will typically be accomplished by setting the room temperature setpoint up and down, opening and closing the sashes on the hoods. Check the operation of all boxes in the zone and ensure that the system tracks correctly in a stable fashion. Refer to the VAV Air Terminal and the applicable Fume Hood functional performance tests for further tests on the individual air terminals.

B. Throughout testing, monitor and trend the room pressure differential sensors.

C. Check the room pressure at both minimum and maximum conditions and while the system is controlling mid range to ensure that the tracking is adequate and stable.

D. Cause all applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.

E. Refer to Division 15 for additional testing requirements.

3.16 LAB VAV GENERAL EXHAUST AND SUPPLY AIR TERMINAL

A. Refer to the HVAC VAV Air terminal FPT for individual box testing. All tests indicated therein apply.

B. Refer to Zone Air Flow Tracking System for lab zone related tests.

C. Refer to the Modified ASHRAE 110 Test for fume hood.

3.17 VAV FUME HOOD

A. Check the stability of the airflow control.

B. Measure the face velocity profile with sash at minimum and maximum positions. Verify that the face velocity at a stable control position is within an acceptable range.

C. Select a representative face velocity sampling location and monitor the control loop response to the moving of the hood. Ensure the loop response is fast and stable. Record the length of time that it takes to the face velocity fluctuation to stay within the range and 10 percent of the target face velocity.

D. Set the zone air flow to maximum and use puffers or smoke generators near the face of the hood to test capture at various sash positions. Operate any adjacent doors or windows that may affect the capture. Identify any room air drafts that are in excess of 50 percent of the nominal face velocity. Check for cross currents at the face of the Fume Hood and correct as necessary.

E. Conduct As-installed Field test in accordance with ASHRAE 110-1995.

F. Refer to Division 11 Section(s) regarding Laboratory Equipment - Fume Hoods and Cabinets for additional requirements.
3.18 CONSTANT VOLUME FUME HOOD

A. Where applicable, measure the face velocity profile with sash at minimum and maximum positions. Verify that the face velocity is within an acceptable range.

B. Set the zone air flow to maximum and use puffers or smoke generators near the face of the hood to test capture at various sash positions. Operate any adjacent doors, windows, or cross currents that may affect the capture. Identify any room air drafts that are in excess of 50 percent of the nominal face velocity.

C. Check the stability of the airflow control.

D. Conduct As-installed Field test in accordance with ASHRAE 110-1995.

E. Refer to Division 11 Equipment Section(s) regarding Laboratory Equipment - Fume Hoods and Cabinets for additional requirements.

3.19 LAB COMPRESSED AIR SYSTEM

A. Verify automatic drain operation of the receiver tank.

B. Monitor normal operation of the compressor. Time run and off cycles to ensure proper operation (per the manufacturer's recommendations). Bleed air at variable rates by opening lab outlets to ensure capacity. Verify adequate air pressure at spot checked outlets.

C. Open disconnect on one compressor and validate the standby operation of the other compressor.

D. Decrease load until tank pressure is satisfied and the air compressor turns off.

E. Create a small load on the system to automatically start one of the compressors.

F. Increase the system load to enable the pressure to continue to drop below the ability of one compressor output.

G. Reduce demand for air. Note the pressures that the lag and lead compressor shut down. Decrease load as needed although record accurate readings.

H. Load system to start lead compressor.

I. Induce the pressure to trigger the BMS pressure alarm.

J. Record the BMS reporting on pressure alarm.

K. Allow the lab air compressor to supply the controls air supply.

L. Send a compressor general alarm to the BMS. Repeat test for the other compressor if there is individual alarm.

M. Record the start and stop times for two cycles.

N. Return system to normal. List any discrepancies or retesting needed.

O. Check oil trap filters on the discharge piping.
3.20 LAB VACUUM SYSTEM

A. Monitor normal operation of the vacuum pump. Time run and off cycles to ensure proper operation (per the manufacturer's recommendations). Admit air at variable rates by opening lab outlets to ensure capacity. Ensure proper rotation of compressors.

B. Open disconnect on one compressor and validate the standby operation of the compressor.

C. With no vacuum demand, system will be satisfied and not run.

D. Isolate the vacuum skid from the field piping. Remove the 5-minute delay in alarming if possible. Slowly bleed the piping so the pressure in the piping rises. Record the gauge pressure at which the BMS receives the alarm.

E. Slowly bring the piping system pressure back down to normal. Record the pressure at which the alarm is returned to normal.

F. Jump alarm input to the BMS and time the alarm delay.

G. Either set the pump panel into alarm or jump the panel alarm point termination at the panel.

H. Cycle the pressure in the system to demonstrate pump lead/lag switch over.

I. Increase load to show system will provide two pumps if load is high.

J. With no vacuum demand in the building, Induce system to cycle and come to a normal stop. Use the BMS to trend pump start times.

K. Demonstrate pump feedbacks are assigned to the proper pumps. Fail one pump and verify second pump starts.

L. Place all system components to normal. List any discrepancies or items that need to be retested. Print trend and provide after 48 hours.

3.21 LAB CYLINDER GAS SYSTEM

A. Test adequate pressure and flow to random outlets throughout the facility.

B. Check all indications and safeties.

3.22 PURIFIED AND DEIONIZED WATER SYSTEM

A. With system in normal operation vary system load by opening faucets. Check system near design capacity. Take one deionized (DI) column out for service. Record flow, pressures, resistivity at various positions.

B. Verify one unit is on-line and the other is in standby. Create an alternation signal from the alternator controller. Verify back-up unit comes on line. Verify lead unit begins regeneration cycle.

C. Verify multimedia filter is in normal operation. Have manufacturer set backwash for minimum time cycle. Verify backwash effluent from filter at drain does not contain filter media.
D. Command a DI pump to start from the Controller. Verify in the field the pump starts. Command the pump to stop from the Controller. Verify in the field the pump stops. While pump is running simulate a loss of discharge pressure by jumping the PSL switch.

E. Test pumps in accordance with the HVAC pump FPT and OT.

F. Manipulate systems to cause all safeties to trip and enunciate.

G. Test and verify water quality, submit test results. If test fails, correct deficiency and re-test.

H. Rest and verify all alarms and the interface with building EMS.

3.23 AUTOMATIC TEMPERATURE CONTROLS

A. Refer to Division 15 Mechanical for DCC, EMS and Laboratory Airflow Control commissioning requirements.

3.24 VIVARIUM ENVIRONMENT TESTING AND MONITORING

A. Establish the required trends for all points associated with the Vivarium.

B. Install portable heaters and humidifiers in the space with capacities within the requirements of the HVAC system. Randomly energize and de-energize these in randomly selected spaces throughout the testing period. Simulate animal loading at various levels in the spaces.

C. Activate lighting control system.

D. Spot check accuracy of sensed variables at a sample rate of 50 percent and a max fail rate of 10 percent. Measure room differential pressures under stable conditions with doors closed.

E. All reports required for Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC) certification shall be printed covering a minimum of a 14 day period. Reports shall demonstrate compliance with the requirements.

3.25 WARM AND COLD ROOMS

A. Change setpoints on all variables controlled to verify control and capacity. Observe loop response and validate that the steady state control is within required tolerance. Room temperature control shall be within plus or minus 1/2 degree F of design value.

B. Test all alarming and enunciation functions. Validate warning setpoints are entered and functional.

C. Review graphic for the following points;

1. high room temp alarm
2. low room temp alarm
3. common trouble alarm
4. equipment failure status
5. 

room temp indication

D. Initiate each alarm point from the environmental room.

E. Record the alarm is received correctly. Use the table below:

1. 1- high room temp alarm    ___
2. low room temp alarm       ___
3. common trouble alarm      ___
4. equipment failure status  ___
5. room temp indication      ___

F. Change the room temp. Alarm setpoint to a lower value than present room temp. Clock the delay time in which the alarm is received. (5 minutes, maximum)

G. Change the room temp. Alarm setpoint to a higher value than present room temp. Clock the delay time in which the alarm is received. (5 minutes, maximum)

H. Write down any test failures or items to retest.

3.26 EMERGENCY GENERATORS AND EMERGENCY DISTRIBUTION SYSTEM

A. Open normal main breakers to simulate power outages.

B. With each outage test configuration, observe generators start and record load. Record volts, amps, frequency, and power factor phase angle for all phases for all generators. Monitor all engine accessories including but not limited to temperature, battery charge, oil pressure, etc. Record all meter readings including current settings and adjustment parameters.

C. With each partial outage, record timing parameters of tie breaker closure.

D. Observe fuel delivery capacity at peak loads. Fail sample delivery systems de-energizing the feed pumps. Verify low level alarms on the fuel tanks.

E. With systems operating on emergency power, spot check power parameters of all systems on emergency power. Emergency testing of individual systems are covered under those systems. In conjunction with the generator testing, test the Uninterruptible Power Systems (UPS). Refer to that item below for more detail.

F. Measure noise levels.

G. Restore normal breakers and observe systems retransfer to normal. Record timing of tie breakers opening. Observe generator cool down and shut down sequence and record parameters.

H. Field Quality Control shall be in accordance with Division 16 Section(s) regarding Engine Generator System.

I. Provide all softwares and hardwares including special tools required for maintenance and troubleshooting.

3.27 SWITCHGEAR

A. Test the operation of the protective relaying and validate the digital metering.
B. Test the mechanical (key) interlocks for generator and service switchgear as applicable.

C. Adjust all operating mechanisms for free mechanical movement.

D. Touch-up scratched or marred surfaces to match original finish to the satisfaction of the University's Representative or replace with new.

E. Check and verify all accessories are functioning. Correct deficiencies.

F. Test local ground fault. Correct deficiencies and record results.

G. Conduct operational and functional tests of digital metering.

H. Perform electrical and mechanical (key) interlock system operational tests on service switchgear.

3.28 MOTOR CONTROL CENTERS (MCC)

A. Test the operation of the starters under load in Hand and Off. Correct deficiencies, retest and record results. Automatic control shall be tested with the FPT of the device.

B. Check and verify all accessories are functioning. Correct deficiencies.

C. Check and verify each motor starter to ensure that heaters and overloads are the correct size for each load.

3.29 DISTRIBUTION PANELBOARDS AND ASSOCIATED LOADS

A. Spot check phase balance. Measure steady state load at each panel board feeder. Should the difference at any panel board between phases exceed 20 percent, rearrange circuits in the panel board to balance the phase loads within 20 percent. Take care to maintain proper balancing for multi-wire branch circuits. Ensure proper, thorough and accurate identification of load. Open all breakers and validate loads identified. Test Ground Fault Interrupter (GFI) breakers.

B. Receptacle Polarity Test: Spot check receptacles installed or reconnected with a receptacle circuit tester. Tester shall test for open ground, reverse polarity, open hot, open neutral, hot and ground reversed, hot or neutral and hot open.

C. Ground-Fault Receptacle Circuit Interrupter Tests: Test each receptacle or branch circuit breaker having ground-fault circuit protection to assure that the ground-fault circuit interrupter will not operate when subjected to a ground-fault current of less than 4 milliamperes and will operate when subjected to a ground-fault current exceeding 6 milliamperes. Perform testing using an instrument specifically designed and manufactured for testing ground-fault circuit interrupters. "TEST" button operation on face of device will not be acceptable as a substitute for this test. Replace receptacles that do not shutoff power with 5/1000 of an ampere within 1/40th of a second and retest. Correct deficiencies and submit test report.
3.30 DISTRIBUTION TRANSFORMERS
A. Simulate design conditions, measure and record temperature at all bolted connections. Check all gauges to confirm compliance. Verify all accessories are functioning. Correct deficiencies and record results.
B. Refer to Division 16 Electrical Section(s) for additional commissioning requirements related to Distribution Transformers.

3.31 DRY TYPE TRANSFORMERS
A. Simulate design conditions, check and record ambient temperature. Check for excessive noise level. Correct deficiencies and record results.
B. Refer to Division 16 Electrical Section(s) for additional commissioning requirements related to Dry Type Transformers.

3.32 AUTOMATIC TRANSFER SWITCH
A. Observe the transfer switch during power outage simulation (both during outage and retransfer to normal). Validate timing and sequences.
B. Test the load test function and the maintenance bypass function.
C. Provide documentation on all control parameters and current settings.

3.33 LIGHTING AND LIGHTING CONTROL SYSTEM
A. Spot check the lighting systems start up and ensure that the all lamps are operational and fixtures are clean.
B. Spot check occupancy sensor placement and test reliability of activation and deactivation.
C. Test photocells for functionality and accuracy.
D. Spot check switches to ensure proper operation, circuiting and zoning.
E. Spot check lighting schedules to ensure they are programmed as requested by the University’s Representative.
F. Spot check lighting levels to ensure compliance with Illuminating Engineering Society of North America (IES) for the respective occupancy.
G. Automatic Lighting Control Start-up: After the system has been installed, provide the services of a factory-trained representative of the manufacturer on-site to verify correct operation of all system components.
H. Sweeps. 50 percent of the zones with a minimum of 2 zones per controller or relay must be verified by turning on at least 25 percent of the lights in the zone and witnessing an actual sweep. The remainder of the zones must have the programming of their schedules verified.
I. Overrides. 25 percent of the local override switches with a minimum of 4 overrides must be verified by turning the override switches on after a sweep and seeing the lights turn back on. 100 percent of the remainder of the switches should be sight
verified to be in place. For each Zone, enter the number of override switches where functionality was actually witnessed. Verify that the local override only controls the specified zone.

J. Test operation of circuits by changing system Date and Time to cause various circuits to switch modes. For rooms with occupancy sensors, validate the circuit energizes with occupancy in the space after the lights have been swept off.

K. For exterior fixtures, simulate night mode to validate function. Measure and record light level to ensure they meet the requirements and provide adequate security. Check for excessive light level fluctuations or dark spots.

L. Verify programming instructions are included in the control panel.

3.34 FIRE ALARM SYSTEM

A. Comply with National Fire Protection Association (NFPA) 70, 72 and other applicable codes. Submit Fire Alarm in accordance with Division 16 Electrical.

B. Local Pre-Test:

1. Contractor shall test all fire alarm devices, record test result and correct any deficiencies prior to requesting University's Representative to witness pre-test.

2. Upon completion of the above, contractor shall coordinate and schedule Fire Alarm pre-test with University’s Representative. Contractor shall pre-test all Fire Alarm components in accordance with NFPA 72 and the standard pre-test procedures required by University. Pre-test shall be witnessed and approved by University's Representative. Correct deficiencies and record results.

C. Additional tests:

1. Spot-check location of sensors and switches to ensure conformance with requirements.

2. Verify interfaces with all other inter-related systems or equipment including EMS, HVAC systems, etc.

3. Validate output devices (speakers and strobes) meet the NFPA 72 code criteria.

4. Test all functions and sequences associated with the elevator recall system.

5. Activate high temperature detectors in the elevator machine room. Verify all sequences including elevator shunt off, elevator recall including alternate floors when main floor is in alarm.

6. Upon completion of air balance, verify and test differential pressure across the duct detector. Ensure differential pressure meets manufacturer’s requirements. Test shall be performed by a qualified technician using calibrated instrumentation. Correct deficiencies, re-test and record results. A copy of test result required during final test.

7. Upon completion of duct detector differential pressure test with air handler unit in automatic operation operating under design condition, activate
smoke detector and verify all smoke control sequences and ensure fire and smoke dampers actuate as required.

8. Activate a sample of sprinkler flow switches. Validate that appropriate zone enunciates and alarms sound.

9. Verify audio aspects of the system function as required. Verify paging messages can be heard throughout the building.

10. Testing of the HVAC response is included with the associated equipment. Coordinate testing of the fire alarm system with the testing of the individual HVAC systems including shaft pressurization systems.

11. Ensure that the system functions while using all sources of power including normal, emergency, and battery.

D. Remote Central Station Pre-Test:

1. Two separate remote stations Pre-Tests are required.
   a. Remote Station Pre-Test #1 through Facility Fire Alarm System:
      (1) Contractor shall coordinate and schedule fire alarm pre-test with University’s Representative. Contractor shall pre-test 100 percent of the fire alarm devices in accordance with NFPA 72. University's Representative will review the remote signals and programming addresses. A correction list will be developed. Contractor shall correct all deficiencies prior to scheduling the Pre-Test #2.
   b. Remote Station Pre-Test #2 through Campus Fire Department System:
      (1) Contractor shall coordinate and schedule fire alarm pre-test with University's Representative. Contractor shall pre-test 100 percent of the fire alarm devices in accordance with NFPA 72. University's Representative will review the remote signals and programming addresses. A correction list will be developed. Contractor shall correct all deficiencies prior to scheduling the final test.

E. Final Test:

1. Once all pre-test are successfully completed, Contractor shall coordinate with University's Representative to schedule final fire alarm test. Test shall be witnessed and approved by Campus Fire Department.

2. Submit As Built Drawings and complete and sign the NFPA 72 forms in accordance with Section 01334 Shop Drawings, Product Data and Samples.

3. Refer to Division 16 Electrical for additional requirements.

3.35 CARD ACCESS CONTROL AND DOOR ALARM MONITORING SYSTEM

A. Proposed acceptance test procedure shall include the following:

1. Spot check installation and device placement for conformance with the Contract Documents.

2. Issue 3 access cards with varying access levels and spot check access devices (card readers). One of the access cards shall be assigned total access. One
shall be assigned moderate access, and the third minimal. Ensure that access is granted and denied appropriately. Ensure record of entry is received appropriately.

3.36 **TELECOMMUNICATIONS**

A. Refer to Division 16 Electrical Section(s) for additional commissioning requirements related to Telephone and Data Cabling General Requirements.

3.37 **MEDIUM VOLTAGE CABLES**

A. Refer to Division 16 Electrical Section(s) for additional commissioning requirements related to Medium Voltage Cable.

3.38 **ADDITIONAL OPERATIONAL TESTS**

A. Simulate complete building power outage at medium voltage switch or at main transformer and perform the following:
   1. Verify back-up power systems function per contract requirement.
   2. Verify generator transfer time.
   3. Verify all and every equipment/device connected to back-up power system are functional. Record test result.

B. Restore power and perform the following:
   1. Ensure orderly and automatic restart.
   2. Record test result.
   3. Correct deficiencies and re-test. Re-test may occur at main branch circuit if approved by University’s Representative.

C. Contractor shall review Contract Drawings, flow diagrams, single line drawings and sequence of operations to develop a variable system operational testing matrix. The testing matrix shall include various scenarios reflecting actual operating conditions such as equipment failure, temperature control changes, “what if” scenarios and other alarm conditions. Develop and document an operational strategy plan for University’s use during occupancy.

D. After completion of all performance testing and certification by the University’s Representative that all equipment complies with the requirements of the specifications, the Contractor shall operate the building in automatic mode for 48 hours, develop trends and record any failures, alarms and deficiencies using building automatic control system (mechanical and electrical). Adjust all set points to meet day to day operational needs.

E. Upon completion of the above, the Contractor shall operate the building for 7 continuous days, during which all parts of the system shall be operated as a complete facility at various loading conditions, as directed by the University’s Representative. The operational testing period shall commence after the initial period of variable operational tests. The operational testing period shall be a continuous period of not less than 5 days. Should the operational testing period be halted for any reason related to the facilities constructed or the equipment furnished under this contract, or the Contractor's temporary testing systems, the operational
testing program shall be repeated until the specified continuous period has been accomplished without interruption. All systems shall be brought to full operating conditions, including power, controls, temperature, pressure, flow, etc.

F. Develop an operational strategy spread sheet reflecting test results for future University use during occupancy.

END OF SECTION 01662