SECTION 230800 - COMMISSIONING OF HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes Cx process requirements for the following HVAC systems, assemblies, and equipment:

1. Energy supply systems.
2. Heat generation systems.
3. Cooling generation systems.
4. Air, steam, and hydronic distribution systems.
5. BUILDING AUTOMATION SYSTEM (BAS) COMMISSIONING.
6. TAB verification.

B. Related Requirements:

1. For construction checklists, comply with requirements in various Division 23 Sections specifying HVAC systems, system components, equipment, and products.

1.3 DEFINITIONS

A. BAS: Building automation system.

B. Cx: Commissioning, as defined in Section 019113 "General Commissioning Requirements."

C. CxA: Commissioning Authority, as defined in Section 019113 "General Commissioning Requirements."

D. DDC: Direct digital controls.

E. HVAC: Heating, ventilating, and air conditioning.

F. "Systems," "Assemblies," "Subsystems," "Equipment," and "Components": Where these terms are used together or separately, they shall mean "as-built" systems, assemblies, subsystems, equipment, and components.

G. TAB: Testing, adjusting, and balancing.

1.4 INFORMATIONAL SUBMITTALS

A. Qualification Data: For BAS and HVAC Testing Technician.

B. Construction Checklists: Draft construction checklists will be created by CxA for Contractor review.

C. Construction Checklists:

1. Instrumentation and control for HVAC, including the following:

a. Control systems equipment.
b. Control valves.
c. Control dampers.
d. Energy meters.
e. Flow instruments.
f. Gas instruments.
g. Level instruments.
h. Leak-detection instruments.
i. Moisture instruments.
j. Motion instruments.
k. Position instruments.
l. Pressure instruments.
m. Speed instruments.
n. Temperature instruments.
o. Vibration instruments.
p. Weather stations.
q. Sequence of operations.

2. Hydronic piping, including the following:

a. Heating hot-water, chilled-water, and condenser-water piping, fittings, and specialties.
b. Hydronic pumps and motors.
c. Sleeves and sleeve seals.
d. Meters and gages.
e. General-duty and specialty valves.
f. Hangers and supports.
g. Heat tracing.
h. Vibration isolation.

3. Chillers, including the following:

a. Supports and restraints.
b. Trim, accessories, and factory-installed controls.
c. Motors.

4. Mechanical insulation, including the following:

a. Duct and plenum insulation.
b. Fire-suppression, plumbing, and HVAC equipment insulation.
c. Plumbing and HVAC piping insulation.

D. Test equipment and instrumentation list, identifying the following:

1. Equipment/instrument identification number.
2. Planned Cx application or use.
3. Manufacturer, make, model, and serial number.
4. Calibration history, including certificates from agencies that calibrate the equipment and instrumentation.
5. Equipment manufacturers' proprietary instrumentation and tools. For each instrument or tool, identify the following:

a. Instrument or tool identification number.
b. Equipment schedule designation of equipment for which the instrument or tool is required.
c. Manufacturer, make, model, and serial number.
d. Calibration history, including certificates from agencies that calibrate the instrument or tool, where appropriate.

1.5 ADDITIONAL RESPONSIBILITIES

A. Refer to Section 01 91 13019113Contractor responsibilities common to all Divisions are specified in Section 01 91 13. The f019113 additional responsibilities or notable responsibilities specific to Division 23.

B. Construction Phase

1. Provide skilled technicians qualified to perform the work required.
2. Provide factory-trained and authorized technicians where required by the Contract Documents.
3. Prepare and submit required draft Start-Up Documentation and submit along with the manufacturer¢s application, installation and start-up information.
4. Provide assistance to the CxA in preparation of the specific Functional Performance Test (FPT) procedures. Contractors, subcontractors and vendors shall review FPT procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests. Damage caused to equipment performed in accordance with the approved procedures will be the responsibility of the Contractor.

5. Thoroughly complete and inspect installation of systems and equipment as detailed throughout Contract Documents, as required by reference or industry standards, and as specifically indicated elsewhere this Section.
6. Start-Up, test/adjust/balance, and Turn-Over systems and equipment prior to functional performance testing by the CxA. Approved Start-Up Documentation shall be in accordance with Contract Documents, reference or industry standards, and specifically elsewhere in Part I of this Section.
7. Record Start-Up on approved Start-Up Documentation forms and certify that the systems and equipment have been started and or tested in accordance with the requirements specified above and in Section 010900. Each task or item shall be indicated with the Party actually performing the task or procedure.
8. TAB: As outlined in Section 230593. Specifically as it relates to Cx:

    a. Attend Construction Phase Cx Kick-Off Meeting and Cx progress meetings beginning within 3 months of start of TAB work;
    b. Submit TAB Plan as indicated above;
    c. Meet with Cx team to review TAB procedures and documentation required;
    d. Demonstrate TAB procedures for repetitive tasks (zone balancing, AHU adjusting) as called for by the CxA;
    e. Participate in Action List dialogue;
    f. Provide all documentation electronically.
    g. Attend a meeting convened by the CxA to coordinate with the safety certifying agency. The point of the meeting will be to coordinate protocols and measurement approaches to ensure that devices such as fume hoods and biosafety cabinets will be set up to achieve certification.

C. Acceptance Phase

1. Assist CxA in Functional Performance Testing. Assistance will typically include the following:

    a. Manipulate systems and equipment to facilitate Functional Performance Testing
    b. Provide any specialized instrumentation necessary for Functional Performance Testing;
    c. Manipulate BAS and other control systems to facilitate Functional Performance Testing.
    d. Provide a TAB technician to work at the direction of CxA for up to 16 hours beyond assistance specified above.
    e. Provide a BAS technician to work at the direction of CxA for up to 16 hours beyond assistance specified above.
    f. Maintain trends and monitor the facility throughout the Endurance Period.

D. Warranty Phase

1. Maintain record documentation of any configurations, setpoints, parameters, etc. that change throughout the Warranty Period.

2. Provide representative for off-season testing as required by CxA.
3. Respond to warranty issues as required by Division 01 and the General Conditions.

1.6 PIPING CLEANING, FLUSH, AND FILL PLAN

A. Contractors shall provide a ÓPiping Cleaning, Flush, and Fill Plan to the CxA that provides a descriptive narrative and supporting calculations of the means and methods that will be used to clean out, flush, and fill the piping systems.

B. The ÓPiping Cleaning, Flush, and Fill Plan shall incorporate and be inclusive of all requirements of individual Sections relating to piping and pipe cleaning and flushing. In addition to the requirements of any other related Section, this document shall consist of the following at a minimum for each individual hydronic loop:

1. Overview schematic diagram of each of the hydronic systems, showing individual flow components such as chillers, boilers, pumps, heat exchangers, cooling towers, control valves, and strainers.
2. Narrative and illustration indicating the equipment that will either participate or be bypassed by fluid flow during the clean and flush process.
3. For equipment to be bypassed, description of the means for providing the bypass, including the type, size, and length of hoses or piping to be used.
4. Description of how flow is to be induced (permanent pumps, temporary pumps, etc.) and flow rates to be imposed during the flush process.
5. Calculation of resultant flow velocities in various portions of the piping system, with specific identification of the minimum velocity sections of the piping loop. Velocities should generally be shown to be above a 7 feet-per-second minimum speed to provide for adequate capability to flush and carry debris through the system to the appropriate strainer or clean-out location.
6. Description of cleaning methods and materials to be used to flush the system. Description shall include cleaning material and concentration, details of the cleaning process including duration of circulation and flushing intervals, criteria for determining a Óclean flush, and name and qualifications of cleaning or chemical treatment subcontractors to be used.
7. Identification and discussion of any isolated sections or Üdead-legs¢ that will be present, including means to provide cleaning and flushing for these sections.
8. Details of the strainers to be used for the flush and clean process, as well as final strainers to be used after cleaning. Contractor shall clean all strainers prior to turning over the system for commissioning.
9. If the cleaning and flushing process is to be phased in sections, details should be provided to clarify how clean sections will be protected as other sections are flushed.

1.7 TEMPORARY OPERATION AND CONDITIONING PLAN

A. Contractor shall be allowed to use permanent building equipment to provide temporary conditioning ONLY upon the approval of the A/E, Owner, and the CxA. Approval for such will only be given upon acceptance of a detailed Temporary Operating and Conditioning Plan provided by the individually involved subcontractors and compiled by the CM. The Temporary Operating and Conditioning Plan shall consider/address the following at a minimum:

1. Contractor shall address how equipment will be maintained in good, clean condition. Specifically address:
   a. Temporary Filtering of Water and Condensate: Construction strainers shall be used while circulating fluid during construction. Construction strainer shall be finer than that specified for final strainers.
   b. Lubrication and Maintenance: Contractor shall maintain the systems and equipment in accordance with the manufacturer¢s instructions. Contractor shall coordinate lubricants used with Owner¢s operators. Frequency of lubrication and inspection shall be as recommended by manufacturer¢s literature. Applicable maintenance lubrication schedules shall be included in the Plan. Draft maintenance logs shall be submitted with Plan and completed as maintenance is performed.
   c. Operation Outside of Normal Ranges: Systems and equipment shall not be operated outside the range of specified conditions. The Temporary Conditioning Plan shall address how the Contractor will ensure that operation will not harm the equipment.

2. Emergency Condition Identification and Response Protocols: The Temporary Conditioning Plan shall address protocols for responding to equipment malfunctions and or harmful operation. Automatic safeties and remote enunciation shall be in place to protect people and property. Temporary operation shall not be allowed until there is an automatic communication/enunciation medium such as a phone connection or an Internet connection. At a minimum, an alarm on the equipment used for temporary service shall be automatically sent to the Contractor¢s 24 hour monitoring service and to the Owners help desk. The Contractor shall respond to and be responsible for securing conditions within the building.
3. Building Protection: Address how the system will be controlled to avoid humidity conditions that could either promote mold growth or cause corrosion.
4. Equipment Reconditioning: Address with specific means and methods how the equipment used for temporary conditioning will be reconditioned to like-new condition. Belts, seals, bearings, couplings, or other parts that wear more than 3% of their expected life shall be replaced.
5. Cleaning: Address how ducts, pipes, coils, converters, air handling equipment, terminal units, etc. shall be cleaned prior to Turn-Over.
6. Operations Log: Contractor responsible for operating the equipment shall maintain a log of all activities associated with operating and maintaining equipment. Log shall be submitted to Owner on a frequency specified by the Owner.

7. Operating System Alterations: The Temporary Conditioning Plan shall address specific protocol for doing work on the systems.
8. Damages: Any material, device, component, or equipment that is assessed as damaged or as having a substantially shortened life as a result of temporary conditioning operation shall be replaced by the Contractor at no cost to the Owner or to the project.
9. Segregation: Where only portions of a system are to be used, Contractor shall specifically indicate how the used portion will be isolated from the unused portion. The Temporary Conditioning Plan shall address how to ensure that the reduced operation condition will be maintained within acceptable ranges, and/or how capacity will be throttled to keep all operating parameters in recommended ranges.

1.8 QUALITY ASSURANCE

A. BAS Testing Technician Qualifications: Technicians to perform BAS construction checklist verification tests, construction checklist verification test demonstrations, Cx tests, and Cx test demonstrations shall have the following minimum qualifications:

1. Journey level or equivalent skill level with knowledge of BAS, HVAC, electrical concepts, and building operations.
2. Minimum three years' experience installing, servicing, and operating systems manufactured by approved manufacturer.
3. International Society of Automation (ISA)-Certified Control Systems Technician (CCST) Level I.

B. HVAC Testing Technician Qualifications: Technicians to perform HVAC construction checklist verification tests, construction checklist verification test demonstrations, Cx tests, and Cx test demonstrations shall have the following minimum qualifications:

1. Journey level or equivalent skill level. Vocational school four-year-program graduate or an Associate's degree in mechanical systems, air conditioning, or similar field. Degree may be offset by three years' experience in servicing mechanical systems in the HVAC industry. Generally, required knowledge includes HVAC systems, electrical concepts, building operations, and application and use of tools and instrumentation to measure performance of HVAC equipment, assemblies, and systems.
2. Minimum three years' experience installing, servicing, and operating systems manufactured by approved manufacturer.

C. Testing Equipment and Instrumentation Quality and Calibration:

1. Capable of testing and measuring performance within the specified acceptance criteria.
2. Be calibrated at manufacturer's recommended intervals with current calibration tags permanently affixed to the instrument being used.
3. Be maintained in good repair and operating condition throughout duration of use on Project.
4. Be recalibrated/repaired if dropped or damaged in any way since last calibrated.

D. Proprietary Test Instrumentation and Tools:

1. Equipment Manufacturer's Proprietary Instrumentation and Tools: For installed equipment included in the Cx process, test instrumentation and tools manufactured or prescribed by equipment manufacturer to service, calibrate, adjust, repair, or otherwise work on its equipment or required as a condition of equipment warranty, shall comply with the following:

a. Be calibrated by manufacturer with current calibration tags permanently affixed.
b. Include a separate list of proprietary test instrumentation and tools in operation and maintenance manuals.
c. HVAC proprietary test instrumentation and tools become property of Owner at the time of Substantial Completion.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 CONSTRUCTION CHECKLISTS

A. Prepare detailed construction checklists for following HVAC systems, assemblies, subsystems, equipment, and components:

1. Energy supply systems, including the following:

a. Central-plant steam supply.
b. Central-plant hot-water supply.

2. Cooling generation systems, including the following:

a. Water chillers.

3. Air, steam, and hydronic distribution systems, including the following:

a. Hydronic systems.

4. Controls and instrumentation.
5. TAB verification.

3.2 CONSTRUCTION CHECKLIST REVIEW

A. Review and provide written comments on draft construction checklists. CxA will create required draft construction checklists and provide them to Contractor.

B. Return draft construction checklist review comments within 10 days of receipt.

C. When review comments have been resolved, the CxA will provide final construction checklists, marked "Approved for Use, (date)."

D. Use only construction checklists, marked "Approved for Use, (date)."

3.3 Cx TESTING PREPARATION

A. Certify that HVAC systems, subsystems, and equipment have been installed, calibrated, and started and that they are operating according to the Contract Documents and approved submittals.

B. Certify that HVAC instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents and approved submittals, and that pretest set points have been recorded.

C. Certify that TAB procedures have been completed and that TAB reports have been submitted, discrepancies corrected, and corrective work approved.

D. Set systems, subsystems, and equipment into operating mode to be tested according to approved test procedures (for example, normal shutdown, normal auto position, normal manual position, unoccupied cycle, emergency power, and alarm conditions).

3.4 Cx TEST CONDITIONS

A. Perform tests using design conditions, whenever possible.

1. Simulated conditions may, with approval of Architect, be imposed using an artificial load when it is impractical to test under design conditions. Before simulating conditions, calibrate testing instruments. Provide equipment to simulate loads. Set simulated conditions as directed by CxA and document simulated conditions and methods of simulation. After tests, return configurations and settings to normal operating conditions.
2. Cx test procedures may direct that set points be altered when simulating conditions is impractical.
3. Cx test procedures may direct that sensor values be altered with a signal generator when design or simulating conditions and altering set points are impractical.

B. If tests cannot be completed because of a deficiency outside the scope of the HVAC system, document the deficiency and report it to Architect. After deficiencies are resolved, reschedule tests.

C. If seasonal testing is specified, complete appropriate initial performance tests and documentation and schedule seasonal tests.

3.5 Cx TESTS COMMON TO HVAC SYSTEMS

A. Measure capacities and effectiveness of systems, assemblies, subsystems, equipment, and components, including operational and control functions, to verify compliance with acceptance criteria.

B. Test systems, assemblies, subsystems, equipment, and components operating modes, interlocks, control responses, responses to abnormal or emergency conditions, and response according to acceptance criteria.

C. Coordinate schedule with, and perform Cx activities at the direction of, CxA.

D. Comply with construction checklist requirements, including material verification, installation checks, startup, and performance tests requirements specified in Division 23 Sections specifying HVAC systems and equipment.

E. Provide technicians, instrumentation, tools, and equipment to perform and document the following:

1. Construction checklist verification tests.
2. Construction checklist verification test demonstrations.
3. Cx tests.
4. Cx test demonstrations.

F. Vibration Isolation in HVAC Systems:

1. Prerequisites: Acceptance of results of construction checklists for vibration control devices specified in Section 230548.13 "Vibration Controls for HVAC Piping and Equipment."
2. Components to Be Tested:

    a. Vibration isolation control devices in HVAC systems.
    b. Structural systems.

3. Test Purpose: Evaluate effectiveness of vibration isolation control devices.
4. Test Conditions: Measure vibration of the facility structure at three locations designated by Owner's witness while the isolated equipment operates.

5. Test Conditions: Measure vibration of the facility structure at three locations designated by Owner's witness at the following operating conditions:

   a. Maximum speed.
   b. Minimum speed.
   c. Critical speed.

6. Acceptance Criteria: Structure-borne vibration not to exceed specified performance.

3.6 TAB VERIFICATION

A. Prerequisites: Completion of "Examination" Article requirements and correction of deficiencies, as specified in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

B. Completion of "Preparation" Article requirements for preparation of a TAB plan that includes strategies and step-by-step procedures, and system-readiness checks and reports, as specified in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

C. Scope: HVAC air systems and hydronic piping systems.

D. Purpose: Differential flow relationships intended to maintain air pressurization differentials between the various areas of Project.

E. Conditions of the Test:

1. Cx Test Demonstration Sampling Rate: As specified in "Inspections" Article in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

F. Acceptance Criteria:

1. Under all conditions, rechecked measurements comply with "Inspections" Article in Section 230593 "Testing, Adjusting, and Balancing for HVAC."
2. Additionally, no rechecked measurement shall differ from measurements documented in the final report by more than two times the tolerances allowed.
3. Under all conditions, where the Contract Documents indicate a differential in airflow between supply and exhaust and/or return in a space, the differential relationship shall be maintained.

3.7 ||CENTRAL REFRIGERATION SYSTEM Cx TESTS

A. Start and Stop Condenser-Water Pump(s):

1. Prerequisites: Installation verification of the following:

a. Startup of condenser-water pump(s) .
b. Startup of cooling tower .
c. Input Device: Water pressure transducer .
d. Input Device: DDC system outdoor-air temperature.
e. Input Device: DDC system time schedule.
f. Output Device: Hard wired through motor starter; DDC system binary output.
g. Output Device: Binary output.
h. Display the following at the operator's workstation:

1) Low-level cooling-tower sump alarm.
2) Outdoor-air temperature.
3) Cooling (software) demand indication.
4) Time and time schedule.
5) Condenser-water pump(s) on-off status.
6) Condenser-water pump(s) on-off indication.
7) Condenser-water flow indication.

2. Scope:

a. Condenser-water system, including condenser-water pump(s), cooling towers, and associated controls.

3. Purpose:

a. Condenser-water pump(s) lockout.
b. Condenser-water pump(s) start.
c. Condenser-water pump(s) shutdown.
d. Low-level cooling-tower sump alarm.
e. Condenser-water pump(s) time-of-day schedule.

4. Conditions of the Test:

a. Verify Lockout: Start with condenser-water pump enable-input devices in the "disable" state to prevent pump start. One by one, place the enable-input devices in the "enable" state, and then return each to the "disable" state before placing the next enable-input device to the "enable" state.
b. Verify Start: Start with condenser-water pump enable-input devices in the "disable" state to prevent pump start. One by one, place the enable-input devices in the "enable" state.
c. Verify Shutdown: Place all enable-input devices in the "enable" state to allow the pump(s) to start. One by one, place the enable-input devices in the "disable" state, and then return each to the "enable" state before placing the next enable-input device to the "disable" state.
d. Verify Schedule: Compare condenser-water pump start and stop schedule times with Owner-approved time-of-day schedule.

5. Acceptance Criteria:

    a. Lockout: No single enable-input device starts the pump(s) when released to the "enable" state.
    b. Start: Condenser-water pump(s) start when, and only when, all enable-input devices are in the "enable" state.
    c. Shutdown: Each enable-input device stops the condenser-water pump(s) when placed in the "disable" state, regardless of the state of other enable-input devices.
    d. Schedule: Condenser-water pump start and stop schedule times agree with Owner-approved time-of-day schedule.

B. Start and Stop Chilled-Water Pump(s):

1. Prerequisites: Installation verification of the following:

    a. Startup of chilled-water pump(s) .
    b. Startup of condenser-water pump(s) .
    c. Startup of cooling tower .
    d. Input Device: Flow switch in condenser-water circuit.
    e. Output Device: DDC system command to starter relay.
    f. Display of the following at the operator's workstation:

        1) Chilled-water flow indication.
        2) Condenser-water flow indication.
        3) Chilled-water pump(s) on-off status.
        4) Chilled-water pump(s) on-off indication.

2. Scope: Chilled-water system, including chilled-water pump(s), associated controls, and condenser-water system controls.
3. Purpose:

    a. Chilled-water pump(s) start.
    b. Chilled-water pump(s) shutdown.

4. Conditions of the Test:

    a. Verify Start: Start with chilled-water pump enable-input device in the "disable" state to prevent pump start. Place the enable-input device in the "enable" state.
    b. Verify Shutdown: Start with the enable-input device in the "enable" state to allow the pump(s) to run. Then place the enable-input device in the "disable" state.

5. Acceptance Criteria:

    a. Start: Chilled-water pump(s) start when, and only when, the enable-input device is in the "enable" state.

b. Shutdown: The enable-input device stops the chilled-water pump(s) when placed in the "disable" state.

C. Start and Stop Cooling-Tower Fans(s):

1. Prerequisites: Installation verification of the following:

a. Input Device: Flow switch in condenser-water circuit .
b. Output Device: DDC system command to starter relay.
c. Display:

1) Condenser-water flow indication.
2) Cooling-tower fan(s) on-off indication.

2. Scope: Condenser-water system, including cooling tower, condenser-water pump(s), and associated controls.
3. Purpose:

a. Cooling-tower fan(s) start.
b. Cooling-tower fan(s) shutdown.

4. Conditions of the Test:

a. Verify Start: Start with cooling-tower fan enable-input device in the "disable" state to prevent fan(s) start. Place the enable-input device in the "enable" state.
b. Verify Shutdown: Start with the enable-input device in the "enable" state to allow the fan(s) to run. Then place the enable-input device in the "disable" state.

5. Acceptance Criteria:

a. Start: Chilled-water pump(s) start when, and only when, the enable-input device is in the "enable" state.
b. Shutdown: The enable-input device stops the chilled-water pump(s) when placed in the "disable" state.

D. Alternative Chiller(s):

1. Prerequisites: Installation verification of the following:

a. Input Device: DDC system software.
b. Output Device: DDC system command to chiller terminal strip.
c. Display:

1) Chiller(s) on-off indication.
2) Chiller failure alarm.

2. Scope:

    a. Chilled-water system and associated controls.
    b. Condenser-water system and associated controls.

3. Purpose:

    a. Lead-lag rotation of chillers.
    b. Replacement of failed chiller in rotation.
    c. Adding and dropping chillers as follows: <Insert sequence and parameters>.
    d. Replacement of failed chiller in add/drop sequence.
    e. Chiller failure alarm initiation.

4. Conditions of the Test:

    a. Lead-Lag Rotation - Chiller Start: Create a number of chilled-water system start-stop cycles equal to the number of chillers plus one.
    b. Lead-Lag Rotation - Lead Chiller Fail: Disable the lead chiller while it is running.
    c. Lead-Lag Rotation - Lag Chiller Fail: Disable a lag chiller while it is running.
    d. Lead-Lag Rotation - Chiller Start Fail: Disable a chiller while it is in standby mode. Initiate a lead-lag rotation call for the disabled chiller to start.
    e. Add/Drop Sequence - Increasing Demand: Increase chilled-water demand incrementally to observe the corresponding addition of chillers. Increase demand gradually as the load approaches the set point for adding the next chiller, to permit observation of the actual load at the time the next chiller is enabled.
    f. Add/Drop Sequence - Decreasing Demand: Decrease chilled-water demand incrementally to observe the corresponding dropping of chillers. Decrease demand gradually as the load approaches the set point for dropping the next chiller, to permit observation of the actual load at the time the next chiller is disabled.

5. Acceptance Criteria:

    a. Lead-Lag Rotation - Chiller Start: On each chilled-water system start event, the other chiller in rotation starts as the lead chiller, and the previous lead chiller is designated as the last lag chiller.
    b. Lead-Lag Rotation - Lead Chiller Fail: When the lead chiller fails, the other chiller in rotation starts as the lead chiller, and a chiller failure alarm is initiated for the failed chiller.
    c. Lead-Lag Rotation - Lag Chiller Fail: When the lag chiller fails, the next chiller in rotation starts as the lead chiller, and a chiller failure alarm is initiated for the failed chiller.
    d. Lead-Lag Rotation - Chiller Start Fail: When a chiller fails to start, the next chiller in rotation starts in its place, and a chiller failure alarm is initiated for the failed chiller.

e. Add/Drop Sequence - Increasing Demand: Chillers are added at the specified load set point, plus or minus 5 percent. Chilled-water supply temperature remains stable within plus or minus 2.0 deg F of set point.
f. Add/Drop Sequence - Decreasing Demand: Chillers are dropped at the specified load set point, plus or minus 5 percent. Chilled-water supply temperature remains stable within plus or minus 2.0 deg F of set point.
g. Add/Drop Sequence - Operating Chiller Fail: When an operating chiller fails, the next chiller in sequence starts and a chiller failure alarm is initiated for the failed chiller.
h. Add/Drop Sequence - Chiller Start Fail: When a chiller fails to start, the next chiller in sequence starts in its place and a chiller failure alarm is initiated for the failed chiller.

3.8 BUILDING AUTOMATION SYSTEM (BAS) COMMISSIONING

A. WORK INCLUDED

1. BAS Start-Up and Functional Performance Testing.
2. Validation of proper and thorough installation of BAS and associated equipment.
3. Generic Start-Up Documentation for BAS.
4. Development of final Start-Up Documentation for BAS.
5. Functional Performance Testing of BAS.
6. Coordination of BAS-related training.
7. Documentation of BAS Operation and Maintenance Documentation.

B. GENERAL DESCRIPTION

1. This section defines responsibilities of the Building Automation System Contractor to commission the BAS.
2. Commissioning (Cx) is the process of ensuring that (i) all building systems are installed and perform interactively according to the design intent; (ii) that systems are efficient and cost effective and meet the Owner's operational needs; (iii) that the installation is accurately documented; and (iv) that the Operators are adequately trained. Commissioning serves as a tool to minimize post-occupancy operational problems, and establishes testing and communication protocols to advance the building systems from installation to optimized, fully-dynamic operation.
3. Commissioning Authority (CxA) shall work with the Contractor and the design engineers to direct and oversee the Cx process and perform Functional Performance Testing.
4. The Commissioning Plan outlines the Cx process beyond the Construction Contract, including design phase activities and design team/owner responsibilities. The specification Sections dictate all requirements of the commissioning process relative to the construction contract. The Cx Plan is not part of the construction contract, although it is available for reference at the request of the Contractor.

C. SCOPE

1. The scope of Commissioning on this project shall include the entire BAS system.

D. DEFINITIONS AND ABBREVIATIONS

1. Refer to Section 019113 for a complete list of Definitions and Abbreviations.
2. POT (Portable Operators Terminal): Portable operator workstation (typically a laptop computer) that has BAS software loaded and the capability to access, program, and edit the BAS.
3. HHD (Hand-Held Device): Portable device (typically with limited functionality) that is used to access components of the BAS. May be a standard PDA or proprietary device/interface.

E. CONTRACTOR RESPONSIBILITIES

1. General responsibilities of the BAS Contractor (BAC) are specified in Section 01 91 13019113wing indicate additional specific responsibilities of the BAS Contractor.
2. Assist CxA in verification and Functional Performance Testing. Assistance will typically include the following:

    a. Establish trend logs of system operation as specified herein.
    b. Manipulate systems and equipment to facilitate Functional Performance Testing. Typically, this will only be for initial samples of like systems.
    c. Provide POTs or operator workstations in locations convenient to testing activities as specified below.
    d. Provide CxA with appropriate passwords, keys, and access to control panels and workstations.
    e. Where control systems do not allow a test mode or the overriding of physical input values for testing, program an interim virtual point for all inputs that can be used to represent the point and be overridden for testing.

3. Provide a control technician to work at the direction of the CxA for software optimization assistance for a minimum of 40 hours during the Acceptance Phase of the project.
4. Controls Parameter Matrix: Contractor shall provide a form summarizing all setpoints and alarm parameters and alarming strategies for the Owner to complete. Organize a meeting to discuss the desired initial setpoints and alarm parameters. Contractor shall enter the requested setpoints and alarm parameters at completion of start-up and record the applicable settings in the Start-Up Documentation.

F. Final Systems Operation Training: The BAC shall train the Owner and Operators on whole-building operation and use of the BAS. This training shall focus primarily on BAS control of building systems and operation and its impact on building performance, and shall be conducted after Functional Completion. Additional information is provided in Section 01 91019101MENTATION

1. General: All testing equipment used by any Party shall be of sufficient quality and accuracy to test and/or measure system performance with the tolerances specified. If not otherwise noted, the following minimum requirements apply:

    a. Temperature sensors and digital thermometers shall have a certified calibration within the past year and a resolution of +/- 0.1°F.
    b. Pressure sensors shall have an accuracy of +/- 2.0% of the value range being measured (not full range of meter) and have been calibrated within the last year.
    c. All equipment shall be calibrated according to the manufacturer¢s recommended intervals. Calibration tags shall be affixed or certificates readily available.

2. Standard Testing Instrumentation: Standard instrumentation used for testing air and water flows, temperatures, humidity, noise levels, amperage, voltage, and pressure differential in air and water systems related to functional testing shall be provided by CxA.
3. Special Tools: Special equipment, tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment, according to these Contract Documents shall be included in the base bid price to the Contractor and turned over to the Owner upon project completion.

G. TAB & COMMISSIONING Portable operators terminal

1. Provide the CxA with all software, connection devices, licenses, passwords, etc. to facilitate connection to the BAS throughout the building. Provide a license to graphic software, and all operating software necessary for testing and configuration of all control elements at all levels. License may be a temporary license that will expire after the completion of the Warranty Period. Options include:

    a. A laptop computer provided by BAS Contractor for dedicated use by the CxA throughout the Construction and Acceptance Phases. This would be turned over to the Owner at the end of the Acceptance Phase.
    b. Browser access to the full graphic software: CxA will provide laptop, however BAS Contractor shall set up the laptop to successfully connect.
    c. Licensed client software to be installed on CxA computer: BAS Contractor shall install the software and ensure it is functional.
    d. Terminal Services session access to a graphic server with required CALs to allow use of all required software. BAS Contractor shall configure the CxA computer to connect to the terminal session.

2. Access to the BAS must be provided throughout the building as more fully defined as follows:

    a. Full wireless connection to the graphic server throughout the building will be adequate.
    b. Network connection for full access to the graphic server within 50¢ of any point in the building.

c. Exception to 1 and 2 above: An acceptable alternative to full building access to the graphic server relating to terminal controls shall be providing to the CxA the devices and software required to connect to local terminal controllers through a connection port in the space such as connection to a jack on the temperature sensor (basically what is required by TAB specified below). This does not apply to mechanical rooms as full graphic access is required in mechanical rooms.

3. Provide software required by TAB to calibrate all flow sensors. TAB will provide computer to be used as a portable operator¢s terminal. Any manufacturer specific hardware such as connection cables, converters, hand held devices, etc. shall be provided by the BAS Contractor.
4. Connections shall be provided local to the device being calibrated. For instance, for VAV boxes, connection of the operator¢s terminal shall be either at the sensor as well as at the box. Otherwise a wireless system shall be provided to facilitate this local functionality.

H. BAS Start-Up TESTING, ADJUSTING, CALIBRATION

1. BAS work and/or systems shall be fully functioning prior to Demonstration and Acceptance Phase. Contractor shall start, test, adjust, and calibrate all work and/or systems under this contract, as described below:

   a. Inspect the installation of all devices. Review the manufacturer¢s installation instructions and validate that the device is installed in accordance with them.
   b. Verify proper electrical voltages and amperages, and verify that all circuits are free from faults.
   c. Verify integrity/safety of all electrical connections.
   d. Coordinate with TAB Contractor to obtain and with CxA to fine tune control settings that are determined from balancing procedures. Record the following control settings as obtained from TAB Contractor, and note any TAB deficiencies in the BAS Start-Up Documentation:

      1) Optimum duct static pressure setpoints for VAV air handling units.
      2) Minimum outside air damper settings for air handling units.
      3) Optimum differential pressure setpoints for variable speed pumping systems.
      4) Calibration parameters for flow control devices such as VAV boxes and flow measuring stations. BAS Contractor shall provide hand held device as a minimum to the TAB and CxA to facilitate calibration. Connection for any given device shall be local to the device (i.e., at the VAV box or at the thermostat). HHD or POT shall allow querying and editing of parameters required for proper calibration and Start-Up.
      5) Calibration parameters for fume hoods.

e. Test, calibrate, and set all digital and analog sensing and actuating devices. Calibrate each instrumentation device by making a comparison between the BAS display and the reading at the device, using an instrument traceable to the National Bureau of Standards, which shall be at least twice as accurate as the device to be calibrated (e.g., if field device is +/-0.5% accurate, test equipment shall be +/-0.25% accurate over same range). Record the measured value and displayed value for each device in the BAS Start-Up Documentation.

f. Check and set zero and span adjustments for all transducers and transmitters.

g. For dampers and valves:

1) Check for adequate installation including free travel throughout range and adequate seal.
2) Where control loops are sequenced, check for proper control without overlap

h. For actuators:

1) Check to insure that device seals tightly when the appropriate signal is applied to the operator.
2) Check for appropriate fail position, and that the stroke and range is as required and coordinated with the programmed ranges when it is operating under normal conditions.
3) For pneumatic operators, adjust the operator spring compression as required to achieve close off. If positioner or volume booster is installed on the operator, calibrate per manufacturer¢s procedure to achieve spring range indicated. Check split range positioners to verify proper operation. Record settings for each device.
4) Check the stroke and range under actual loading conditions and validate that they correlate with programmed values.
5) For sequenced electronic actuators, calibrate per manufacturer¢s instructions to required ranges.

i. Check each digital control point by making a comparison between the control command at the CU and the status of the controlled device. Check each digital input point by making a comparison of the state of the sensing device and the OI display. Record the results for each device.

j. For outputs to reset other manufacturers devices (such as VSDs) and feedback from them, calibrate ranges to establish proper parameters. Coordinate with representative of the respective manufacturer and obtain their approval of the installation.

k. Verify proper sequences by using the approved Start-Up Documentation to record results. Verify proper sequence and operation of all specified functions.

l. Verify that all safety devices trip at appropriate conditions. Adjust setpoints accordingly.

m. Tune all control loops to obtain the fastest stable response without hunting, offset or overshoot. Record tuning parameters and response test results for each control loop in the BAS Start-Up Documentation. Except from a start-up, maximum allowable variance from setpoint for controlled variables under normal load fluctuations shall be as follows. Within 3 minutes of any step-change (for which the system has the capability to respond) in the control loop, the following tolerances shall be maintained (exceptions noted):

1) Duct air temperature: ±1 deg F
2) Zone temperature: ±3°F within 3 minutes and control within ±2 deg F
3) Chilled water temperatures: ±1 deg F
4) Hot water temperatures: ±2 deg F
5) Duct air pressure: ± 0.25 i.w.g
6) Water pressure: ±1 psig
7) Duct relative humidity: ±3% when adding humidity
8) Zone relative humidity: ±5% when adding humidity
9) Terminal air flow control: ±5% of setpoint. This includes all VAV terminal control and exhausted BSCs, canopy hoods, ventilated cage racks, necropsy tables, and other scientific equipment with supply or exhaust ventilation.
10) Fume hoods: ±10% on full sash travel (from min to max in 3 seconds) within 3 seconds. ±5% when sash is positioned in the controllable range. Refer to Section 15995 for fume hood acceptance requirements.
11) Zone pressurization (on active control systems): ±0.03 i.w.c. with no door or window movements. No high containment space shall go more than 0.15 i.w.c. positive, nor go positive at all for more than 20 seconds.

n. For communication interfaces and BAS control panels:

1) Ensure devices are properly installed with adequate clearance for maintenance and with clear labels in accordance with the record drawings.
2) Ensure that terminations are safe, secure and labeled in accordance with the record drawings.
3) Check power supplies for proper voltage ranges and loading.
4) Ensure that wiring and tubing are run in a neat and workman-like manner, either bound or enclosed in trough.
5) Check for adequate signal strength and acceptable bandwidth utilization on communication networks.
6) Check for stand-alone performance of controllers by disconnecting the controller from the LAN. Verify the event is annunciated at Operator Interfaces. Verify that the controlling LAN reconfigures as specified in the event of a LAN disconnection.
7) Ensure that all outputs and devices fail to their proper positions/states.
8) Ensure that buffered and/or volatile information is retained through power outage.

9) With all system and communications operating normally and all trends functioning, sample and record update/annunciation times for critical alarms fed from the panel to the Operator Interface.
10) Check for adequate grounding of all BAS panels and devices.
11) Run self diagnostic routines and ensure they are functional.
12) Check the memory allocation and loading to ensure adequate and excess capacity is available and that it will not affect control functionality.

o. Coordinate desired initial alarm strategies with Owner's Operators. Set all required alarms and document the initial settings in the Start-Up Documentation.
p. Coordinate all initial setpoints with Owner¢s Operators. Ensure those setpoints are active.
q. For Operator Interfaces:

1) Verify that all elements on the graphics are functional and are properly bound to physical devices and/or virtual points, and that hot links or page jumps are functional and logical.
2) Output all specified BAS reports for review and approval.
3) Verify that the alarm printing and logging is functional and per requirements.
4) Verify that trend archiving to disk and provide a sample to the CxA for review.
5) Verify alarm enunciation functionality. Time delay from actual occurrence to the time updated or enunciated on the screen. Ensure it is per the specified requirements.
6) Verify that real time and historical trends are accessible and viewable in graph format.
7) Verify that paging/dial out alarm annunciation is functional.
8) Verify the functionality of remote OIs and that a robust connection can be established consistently.
9) Verify that required third party software applications required with the bid are installed and are functional.
10) Demonstrate open protocol and custom third party interfaces reliably communicate and check response time.
11) Verify response times and screen update and refresh times are per the requirements.
12) Verify that all custom programs are editable from the OI. Check upload, download, back up and restore capabilities of system configuration information as well as custom programs.
13) Verify schedules are set up and working.
14) Verify Owner stipulated security and permissions is set up and functional.
15) In concert with the Building Power Outage test, validate that critical GUI installations are properly powered by UPS and emergency outlets to keep it functional during a power outage. Validate that the space has adequate lighting to manage the building in the event of an outage.

r. Start-up and check out control air compressors and air drying and filtering systems in accordance with the appropriate section and with manufacturer¢s instructions.

1) Validate adequate drying and pressures.
2) Validate adequate redundancy
3) Validate max run time and cycle time vs manufacturer¢s recommendations
4) Validate that routing of the compressed air does not result in condensation at any point in the system when used with the specified drier.
5) Check all PRVs both primary and back up to ensure adequate functionality and maintenance of downstream pressure.

s. Verify proper interface with Fire Alarm System.
t. Verify proper interface with control panels of equipment with self-contained controls that are being monitored by the BAS.

2. Submit Start-Up Documentation. This shall be completed, submitted, and approved prior to demonstration and Acceptance Phase.

I. SENSOR CHECKOUT AND CALIBRATION

1. General Checkout: Verify that all sensor locations are appropriate and are away from causes of erratic operation. Verify that sensors with shielded cable are grounded only at one end. For sensor pairs that are used to determine a temperature or pressure difference, make sure they are reading within 0.2°F of each other for temperature and within a tolerance equal to 2% of the reading of each other for pressure. Tolerances for critical applications may be tighter.
2. Calibration: Calibrate all sensors using one of the following procedures:

a. Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor at various points across the range. Verify that the sensor reading (via the permanent thermostat, gage or BAS) is within the tolerances specified for the sensor. If not, adjust offset and range, or replace sensor. Where sensors are subject to wide variations in the sensed variable, calibrate sensor within the highest and lowest 20% of the expected range.

b. Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer¢s resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the OI. Record all values and recalibrate controller as necessary to conform to tolerances. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or BAS) is within the tolerances specified. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.

3. Sensor Tolerance: Sensors shall be within the tolerances specified for the device. Refer to Section 230900.

J. LOOP TUNING

1. For all control loops, Contractor shall tune the loops to ensure the fastest stable response without hunting, offset or overshoot with tolerances defined above. Contractor shall introduce upsets to the load when possible to affect response. Otherwise, setpoints can be changed to affect the response.
2. Generally tune loops during periods of high gain.
3. Document all parameters either by capturing text, short interval trends, or screen shots of trend graph documenting the final response.

K. COIL VALVE LEAK CHECK

1. Verify proper close off of the valves. Ensure the valve seats properly by simulating the maximum anticipated pressure difference across the circuit. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Via the OI, command the valve to close. Energize fans. After 5 minutes, observe air temperature difference across coil. If a temperature difference is indicated, and the piping surface temperature entering the coil is within 3°F of the water supply temp, leakage is probably occurring. If it appears that it is occurring, close the isolation valves to the coil to ensure the conditions change. If they do, this validates the valve is not closing. Remedy the condition by adjusting the stroke and range, increasing the actuator size/torque, replacing the seat, or replacing the valve as applicable.

L. VALVE STROKE SETUP AND CHECK

1. For all valve and actuator positions checked, verify the actual position against the OI readout.

2. Set pumps to normal operating mode. Command valve closed, verify that valve is closed, and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position does not reasonably correspond, replace actuator or add pilot positioner (for pneumatics).

M. GRAPHIC COORDINATION

1. The Contractor shall prepare all graphics (only one example graphic is required for typical systems like terminal units) with points embedded for review of CxA and Owner. Owner shall use these graphics to provide direction to Contractor for the required final graphic. All final graphics must be complete and active before functional testing. Any deviation from the approved graphics will be considered a failure from the perspective of the functional test.

N. BAS DEMONSTRATION

1. Demonstrate the operation of the BAS hardware, software, and all related components and systems to the satisfaction of the CxA and Owner. Schedule the demonstration with the Owner's representative 1 week in advance. Demonstration shall not be scheduled until all hardware and software submittals, and the Start-Up Test Report are approved.
2. The Contractor shall supply all personnel and equipment for the demonstration, including, but not limited to, instruments, ladders, etc. Contractor supplied personnel must be competent with and knowledgeable of all project-specific hardware, software, and the HVAC systems. All training documentation and submittals shall be at the job site.
3. Demonstration shall typically involve small representative samples of systems/equipment randomly selected by the Owner and CxA.
4. The system shall be demonstrated following the same procedures used in the Start-Up Test by using the approved Commissioning Checklists. Demonstration shall include, but not necessarily be limited to, the following:

    a. Demonstrate that required software is installed on BAS workstations. Demonstrate that graphic screens, alarms, trends, and reports are installed as submitted and approved.
    b. Demonstrate that points specified and shown can be interrogated and/or commanded (as applicable) from all workstations, as specified.
    c. Demonstrate that remote dial-up communication abilities are in accordance with these Specifications.
    d. Demonstrate correct calibration of input/output devices using the same methods specified for the start-Up tests. A maximum of 10 percent of I/O points shall be selected at random by CxA and/or Owner for demonstration. Upon failure of any device to meet the specified end-to-end accuracy, an additional 10 percent of I/O points shall be selected at random by CxA for demonstration. This process shall be repeated until 100 percent of randomly selected I/O points have been demonstrated to meet specified end-to-end accuracy.

e. Demonstrate that all BAS and other software programs exist at respective field panels. The BAS programming and point database shall be as submitted and approved.
f. Demonstrate that all BAS programs accomplish the specified sequences of operation.
g. Demonstrate that the panels automatically recover from power failures, as specified.
h. Demonstrate that the stand-alone operation of panels meets the requirements of these Specifications. Demonstrate that the panels' response to LAN communication failures meets the requirements of these Specifications.
i. Identify access to equipment selected by CxA. Demonstrate that access is sufficient to perform required maintenance.
j. Demonstrate that required trend graphs and trend logs are set up per the requirements. Provide a sample of the data archive. Indicate the file names and locations.

5. BAS Demonstration shall be completed and approved prior to Functional Performance Testing. CxA shall determine if the system is ready for Functional Performance Testing and document any problems requiring Contractor attention.

   a. If the systems are not ready for Functional Performance Testing, Contractor shall correct problems and provide notification to the Ownerȼs representative that all problems have been corrected. The Acceptance Period shall be restarted at a mutually scheduled time for an additional one week period. This process shall be repeated until CxA issues notice that the BAS is ready for Functional Performance Testing.

6. Any tests successfully completed during the BAS Demonstration will be recorded as ÜPassedȼ for the Functional Performance Testing and will not have to be re-accomplished.

O. FUNCTIONAL PERFORMANCE TESTING

1. Requirements for assistance with Functional Performance Testing are specified in the Section 019113, Section 230800 and Section 260800. Provide assistance during Functional Performance Testing per the Section 019113 and related Specifications.

P. BAS ACCEPTANCE PHASE AND OBSERVATION PERIOD

1. BAS Acceptance Phase: BAS Acceptance Phase consists of the Functional Performance Testing process of the BAS by the CxA and shall begin after approval of the BAS Demonstration and prior to issuance of Substantial Completion. Acceptance Phase for the BAS shall not be scheduled until all HVAC systems are in operation, the Start-Up Documentation has been reviewed, all required cleaning and lubrication has been completed (i.e., filters changed, piping flushed, strainers cleaned, etc.), and TAB report has been submitted and approved. Acceptance Phase and its approval to begin will be performed on a system-by-system basis if mutually agreed upon by Contractor and Owner.
2. BAS Observation Period: After Functional Performance Testing , the BAS shall be shown to operate properly for 2 weeks without malfunction, without alarm caused by control action or device failure, and with smooth and stable control of systems and equipment in conformance with these specifications. At the end of the two weeks, BAS Contractor shall forward the trend logs to the CxA for review.
3. During the Acceptance Phase, the Contractor shall maintain a hard copy log of all alarms generated by the BAS. For each alarm received, Contractor shall diagnose the cause of the alarm, and shall list on the log for each alarm, the diagnosed cause of the alarm, and the corrective action taken. If in the Contractor¢s opinion, the cause of the alarm is not the responsibility of the Contractor, Contractor shall immediately notify the Owner's representative.
4. During the Acceptance Phase, the Contractor shall maintain all controller network and workstation hardware and software in a state that will allow remote access by CxA to trend logs as specified below.

Q. BAS TREND REQUIREMENTS

1. The BAS Contractor shall configure and analyze all trends required under this Section.
2. Trends are historical archives on computer disks that document the operation of the systems and equipment. Trends can be time-series (interval) recordings of system I/O parameters or change-of-value (COV) based trends that record when a system value changes by more than a specified threshold.
3. CxA will analyze trend logs of the system operating parameters to evaluate normal system functionality. The requirements of the trending are specified below. Contractor shall establish these trends, ensure they are being stored properly, and forward the data in electronic format to the CxA.
4. Data shall include a single row of field headings and the data thereafter shall be contiguous. Each record shall include a date and time field. Recorded parameters for a given piece of equipment or component shall be trended at the same time intervals and be presented in a maximum of two separate two dimensional formats with time being the vertical axis and field name being the horizontal axis.. Data shall be forwarded in one of the following formats.

    a. Microsoft Access Database (.mdb)
    b. Microsoft Excel Spreadsheet (.xls)
    c. Comma Separated Value (.csv or .txt), preferably with quotes delimiting text fields and # delimiting date/time fields.

5. Sample times indicated as COV (±) mean that the changed parameter only needs to be recorded whenever the value changes by the amount listed. When output to the trend file, the latest recorded value shall be listed along with the time increment record. If the BAS does not have the capability to record based on COV, the parameter shall be recorded based on the time interval common to other point trends for the system.
6. Contractor shall provide the CxA with required passwords, phone numbers, etc. to allow the CxA access to the trend log data and allow downloading to a remote location. Contractor shall also provide step-by-step written instructions for accessing the data.
7. Trending Requirements: All I/O points on primary equipment shall be trended throughout the Cx process on 10 min. intervals for analog values and change-of-value for binary values. Trends shall include but are not necessarily limited to the following points:

    a. Outside air temperature
    b. Outside air relative humidity
    c. Outside air enthalpy
    d. Cooling tons
    e. All sensed hydronic temperatures
    f. All sensed air temperatures and relative humidity measurements on primary equipment
    g. All damper outputs on primary equipment
    h. All valve outputs on primary equipment
    i. All sensed fan volumes (flow) on primary equipment
    j. All inputs and outputs to Variable Speed Drives
    k. Return (or exhaust) air temperature on each air handler
    l. All safety indications
    m. Status on all primary equipment
    n. All air and water pressures on primary equipment or systems
    o. Zone temperatures
    p. Steam flow
    q. Electricity consumption where monitored.
    r. Natural gas flows
    s. Converter steam valves and hot water temperatures
    t. Steam supply pressures and temperatures.
    u. All points on primary equipment and selected sampling of terminal points unless approved otherwise.

R. TREND GRAPHS

1. Trend graphs shall be used during Functional Performance Testing to facilitate and document testing. Contractor shall prepare controller and workstation software to display graphical format trends throughout the Acceptance Phase. Trend graphs shall demonstrate compliance with contract documents. Trended values and intervals shall be the same as those specified for the Functional Performance Tests.
2. Lines shall be labeled and shall be distinguishable from each other by using either different line types or different line colors.

3. Indicate engineering units of the y-axis values; e.g. degrees F., inches w.c., Btu/lb, percent wide open, etc.
4. The y-axis scale shall be chosen so that all trended values are in a readable range. Do not mix trended values on one graph if their unit ranges are incompatible.
5. Trend outside air temperature, humidity, and enthalpy during each period in which any other points are trended.
6. All points trended for one HVAC subsystem (e.g. air handling unit, chilled water system, etc.) shall be trended simultaneously and on a common trend period.
7. Each graph shall be clearly labeled with HVAC subsystem title, date, and times.
8. The format of all trend graphs must be provided as approved by the CxA.

S. WARRANTY PHASE - OPPOSITE SEASON TRENDING AND TESTING

1. Trending: Throughout the Warranty Phase, trend logs shall be maintained as required for the Acceptance Phase. BAS Contractor shall forward archived trend logs to the CxA for review upon CxA request. CxA will review these and notify BAS Contractor of any warranty work required.
2. Opposite Season Testing: Within 6 months of completion of the Acceptance Phase, CxA shall schedule and conduct Opposite Season Functional Performance Testing. The BAS Contractor shall support this testing and remedy any deficiencies identified.

T. SOFTWARE OPTIMIZATION ASSISTANCE

1. The Contractor shall provide the services of a BAS technician as specified above at the project site to be at the disposal of the CxA. The purpose of this requirement is to make changes, enhancements and additions to control unit and/or workstation software that have been identified by the CxA during the construction and commissioning of the project and that are beyond the specified Contract requirements. The cost for this service shall be included with the bid. Requests for assistance shall be for contiguous or non-contiguous 8-hour days, unless otherwise mutually agreed upon by Contractor, CxA, and Owner. The Owner's representative shall notify Contractor 2 days in advance of each day of requested assistance.
2. The BAS technician provided shall be thoroughly trained in the programming and operation of the controller and workstation software. If the BAS technician provided cannot perform every software task requested by the CxA in a timely fashion, Contractor shall provide additional qualified personnel at the project site as requested by the CxA to meet the total specified requirement per building on-site.

U. BAS OPERATOR TRAINING

1. Provide up to 6 complete sets of User Manuals (hard copy and one electronic copy) to be used for training.
2. BAS Contractor shall submit a Training Plan per the requirements of Div 01 to the CM who will forward it to the A/E and CxA for review.

3. On Site Training: Provide services of BAS Contractor's qualified technical personnel to instruct Owners personnel in operation and maintenance of the BAS. Instruction shall be in classroom setting at the project site for appropriate portions of the training. Training may be in non-contiguous days at the request of the Owner. The Owner's representative shall notify Contractor 1-week in advance of each day of requested training. The Contractor's designated training personnel shall meet with the A/E, CxA and Owner¢s representative for the purpose of discussing and fine-tuning the training agenda prior to the first training session. Training agenda shall be as follows:

   a. Basic Operator Workstation Training:

      1) Brief walk-through of building, including identification of all controlled equipment and condensed demonstration of controller portable and built-in operator interface device display capabilities.
      2) Brief overview of the various parts of the BAS O&M manuals, including hardware and software programming and operating publications, catalog data, controls installation drawings, and BAS programming documentation.
      3) Demonstration of workstation login/logout procedures, password setup, and exception reporting.
      4) Demonstration of workstation menu penetration and broad overview of the various workstation features.
      5) Overview of systems installed.
      6) Present all site-specific naming conventions and points lists, open protocol information, configuration databases, back up sequences, upload/download procedures etc.
      7) Overview of scheduling procedures.
      8) Overview of alarm features, including how to acknowledge, respond to, and archive alarms, and how to access further information from them.
      9) Overview of trend features, including how to set up and view trends.
      10) Overview of workstation reporting features and introductory level report generation and scheduling.

   b. BAS Technician Training:

      1) General review of sequence of operation and control logic for the project site, including standalone and fail safe modes of operation
      2) Uploading/downloading and backing up controller configuration and application programs
      3) Review of installed components including all communication devices, controllers, I/O, etc., and how to install/replace, maintain, commission, and diagnose them
      4) Introduction to controller programming and overview of the programming application interface
      5) Defining trends, generating graphs in real time; archiving trends, accessing historical archive and generating reports from them
      6) Introductory network administration

7) Introduction to creating and editing graphics
8) Review of setpoint optimization and fine-tuning concepts
9) OI use and maintenance
10) Web page creation as applicable

c. System Administrator Training:

1) Overview of system architecture including all routers, bridges, repeaters, gateways, communications protocols, servers, controllers etc.
2) Overview of and recommendations for backing up and restoring the system configuration database
3) Server maintenance
4) Security Management: Assigning passwords and rights for various users on the server, workstations and GUI software

d. Final Systems Operation Training

1) The BAS Contractor shall conduct Final Systems Operation Training in accordance with Section 019113.
2) Final Systems Operation Training provides the Owner and Operators a training session on whole-building operation. It shall focus primarily on BAS control of building systems and operation and its impact on building performance. System interactions shall be presented and discussed (such as a combined air handler, chiller, boiler, and terminal unit system), along with a detailed presentation of the sequences of operation and their relationship to the BAS. This training shall be conducted by the BAC with assistance from the CxA, and shall be attended by the Owner, Operators, Contractor, Design Team, and by any other Cx Team members deemed necessary by the CxA or the Owner.
3) The Record BAS Shop Drawings shall be provided as a handout for the training.
4) Scheduling, attendees, and training methods shall be as specified in Section 019113.
5) The audience for this session shall be the occupants and their representatives. The setting should be in the field at a functioning fume hood.

END OF SECTION