

SECTION 230801 - BAS SYSTEM COMMISSIONING

PART I. GENERAL

I.1 SECTION INCLUDES

- A. BAS and equipment testing and start-up
- B. Validation of proper and thorough installation of BAS and equipment
- C. Functional testing of control systems
- D. Documentation of tests, procedures, and installations
- E. Coordination of BAS training
- F. Documentation of BAS Operation and Maintenance materials

I.2 RELATED SECTIONS:

- A. Drawings and general provisions of Contract, including General and Supplementary Conditions and Division-1 Specification sections, apply to work of this section.
- B. Section ***[Insert Applicable Specification Section]*** - Basic Mechanical Materials
- C. Section 230900 – BAS General Requirements
- D. Section 230901 - BAS Basic Materials and Devices
- E. Section 230903 - BAS Field Panels
- F. Section 230904 - BAS Communication Devices
- G. Section 230905 - BAS Software and Programming
- H. Section ***[Insert Applicable Specification Section]*** – Sequence of Operation

I.3 GENERAL DESCRIPTION

- A. This section defines responsibilities of the Controls Contractor to commission the BAS.
- B. Commissioning is the process of ensuring that all building systems are installed and perform interactively according to the design intent, the systems are efficient and cost effective and meet the owner's operational needs, the installation is adequately documented, and that the Operators are adequately trained. It serves as a tool to minimize post-occupancy operational problems. It establishes testing and communication protocols in an effort to advance the building systems from installation to full dynamic operation and optimization.
- C. Commissioning Authority (CA) and Owner shall work with the Contractor and direct, coordinate, and oversee the Commissioning process and witness functional performance testing. Contractor is required to coordinate with both the Owner and CA to conduct the work and provide sufficient notification to both parties for all activities related to commissioning.

I.4 CONTRACTOR RESPONSIBILITIES

- A. Completely install and thoroughly inspect, startup, test, adjust, balance, and document all systems and equipment.
- B. Assist Commissioning Authority in verification and performance testing. This will generally include the following:
 - 1. Attend Commissioning (Cx) progress and coordination meetings, during functional testing, acceptance and punchlist close out. The number of meetings will vary depending on the complexity of the project.
 - 2. Prepare and submit required draft forms and systems information.
 - 3. Help establish trend logs of system operation as specified herein.
 - 4. Demonstrate system operation.
 - 5. Manipulate systems and equipment to facilitate testing.
 - 6. Provide instrumentation necessary for verification and performance testing.
 - 7. Manipulate control systems to facilitate verification and performance testing.
 - 8. Train Owner's Representatives as specified in Part III of this section.

AE shall specify the amount of software optimization hours appropriate for the size and complexity of the project, Edit accordingly. Typically 40 hours for a laboratory & 24 for a major, non-laboratory.

- C. Contractor is required to coordinate with both the Owner and CA to conduct the work and provide sufficient notification to both parties for all activities related to commissioning.
- D. Provide a BAS Technician to work at the direction of Commissioning Authority for software optimization assistance for a minimum of **XX** hours. Refer to Part 3 for a description of the software optimization.
- E. **Compensation for Retesting:** Contractor shall compensate Owner for site time necessitated by incompleteness of systems or equipment at time of functional performance testing. All testing failures, which require on-site time for retesting, will be considered actual damages to the Owner. All parties under contract with the Owner who are affected by the retesting shall be included in the contract modification.

I.5 SEQUENCING

- A. The following list outlines the general sequence of events for submittals and commissioning:
 - 1. Submit product data and shop drawings, and receive approval.
 - 2. Submit BAS logic documentation, and receive approval.
 - 3. Submit Start-Up Checklists and manufacturer's start-up procedures for all equipment provided by the BAS Contractor.
 - 4. Install BAS.
 - 5. Submit BAS Start-Up Test Agenda and Schedule for review.
 - 6. Receive BAS Startup Test Agenda/schedule approval.
 - 7. Submit Training Plan.
 - 8. Simulate sequencing and debug program off-line to the extent practical.

9. Place systems under BAS control where applicable during a scheduled outage.
10. Perform BAS Startup where applicable during a scheduled outage.
11. Prepare and initiate trend log data storage and format trend graphs.
12. Submit completed BAS Start-Up Reports and initial draft of the O&M Manuals.
13. Receive BAS Startup Report approval and approval to schedule Demonstrations and Commissioning.
14. Demonstrate systems to [Commissioning Authority] [and] [Owner].
15. Receive demonstration approval and approval to schedule Acceptance Period.
16. Train Owner on BAS operation and maintenance.
17. Substantial Completion
18. Begin Acceptance Phase.
19. Two week Operational Test.
20. Perform Functional Performance Testing.
21. Receive Acceptance Period approval, which is Functional Completion for the BAS.
22. Train Owner on final sequences and modes of operation.
23. Install framed control drawings.
24. Provide Level 1 password access to the Owner.
25. Revise and re-submit record drawings and O&M Manuals.
26. Final Acceptance.
27. Begin Warranty Phase.
28. Schedule and begin Opposite Season acceptance period.
29. Receive Opposite Season acceptance period approval.
30. Submit as-built drawings and O&M Manuals.
31. Update framed control drawings.
32. Complete Owner Training (*Designer to coordinate actual hour training requirement see 230900/3.6*).
33. End-of-Warranty date/period.

PART II. PRODUCTS

II.1 INSTRUMENTATION

- A. Instrumentation required to verify readings and test the system and equipment performance shall be provided by Contractor and made available to Commissioning Authority. Generally, no testing equipment will be required beyond that required to perform Contractors work under these Contract Documents. All equipment used for testing and calibration shall be NIST/NBS traceable and calibrated within the preceding 6-month period. Certificates of calibration shall be submitted.
- B. *Designer to ask UNC (per project) whether this tool is required* Provide a network bandwidth analysis tool. The tool for determining bandwidth utilization shall be the LoyTech protocol analyzer LPA-IP network analysis tool, no exceptions allowed. Provide hardware and Protocol Analyzer Software. Turn the tool over to UNC as part of the Project Closeout requirements.

II.2 TAB & COMMISSIONING PORTABLE OPERATORS TERMINAL

- A. For new projects and HVAC renovations, Contractor shall provide a portable operators terminal or hand held device to facilitate Testing, Adjusting, and Balancing (TAB) and calibration. This device shall support all functions and allow querying and editing of all parameters required for proper calibration and Startup. Contractor, at the completion of the work, shall provide to the Owner all hardware, software, cables, power supplies, converters necessary for operation with the Owner's existing POTs to provide the ability to perform the functions of this device.
- B. Connections shall be provided local to the device being calibrated. For instance, for VAV boxes, connection of the operator's terminal shall be provided at the sensor. Otherwise a working wireless system shall be provided to facilitate this local functionality.

PART III. EXECUTION

III.1 BAS START-UP TESTING, ADJUSTING, CALIBRATION

- A. Work and/or systems installed under this Division 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:
 - 1. Inspect the installation of all devices. Review the manufacturer's installation instructions and validate that the device is installed in accordance with them.
 - 2. Verify proper electrical voltages and amperages, and verify that all circuits are free from faults.
 - 3. Verify integrity/safety of all electrical connections. Coordinate with TAB subcontractor to obtain 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 Report:
 - a) Optimum duct static pressure setpoints for VAV air handling units.
 - b) Minimum outside air damper settings for air handling units.
 - c) Optimum differential pressure setpoints for variable speed pumping systems.
 - d) Calibration parameters for flow control devices such as VAV boxes and flow measuring stations.
 - 1) BAS contractor shall provide hand-held device as a minimum to the TAB and CA to facilitate calibration. Connection for any given device shall be local to it (i.e. at the VAV box or at the thermostat). Hand-held device or portable operator's terminal shall allow querying and editing of parameters required for proper calibration and start-up.
 - 5. 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 Startup Report.

6. Check and set zero and span adjustments for all transducers and transmitters.
7. For dampers and valves:
 - a) Check for adequate installation including free travel throughout range and adequate seal.
 - b) Where loops are sequenced, check for proper control without overlap.
8. **For actuators:**
 - a) Check to insure that device seals tightly when the appropriate signal is applied to the operator.
 - b) Check for appropriate fail position, and that the stroke and range is as required.
 - c) 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 in the BAS Pre-Commissioning Report.
 - d) For sequenced electronic actuators, calibrate per manufacturer's instructions to required ranges.
9. 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 Operator Interface display. Record the results for each device in the BAS Start-Up Report.
10. For outputs to reset other manufacturer's devices (for example, VSDs) and for feedback from them, calibrate ranges to establish proper parameters. Coordinate with representative of the respective manufacturer and obtain their approval of the installation.
11. Verify proper sequences by using the approved checklists to record results and submit with BAS Start-Up Report. Verify proper sequence and operation of all specified functions.
12. Verify that all safety devices trip at appropriate conditions. Adjust setpoints accordingly.

AE shall provide the tolerances for the type and criticality of the area or zone being served by the equipment. AE may have to specify two or more sets of tolerances for a specific project. Edit accordingly

13. 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 Startup Report. Except from a startup, maximum allowable variance from set point for controlled variables under normal load fluctuations shall be as follows. Within 3 minutes of any upset (for which the system has the capability to respond) in the control loop, tolerances shall be maintained (exceptions noted):
 - a) Duct air temperature: $\pm 1^{\circ}\text{F}$.
 - b) Space Temperature: $\pm 2^{\circ}\text{F}$

- c) Chilled Water: $\pm 1^{\circ}\text{F}$
- d) Hot water temperature: $\pm 3^{\circ}\text{F}$.
- e) Duct pressure: $\pm 0.25'' \text{ w.g.}$
- f) Water pressure: $\pm 1 \text{ psid}$
- g) Duct or space Humidity: $\pm 5\%$
- h) Air flow control: $\pm 5\%$ of setpoint velocity.

14. **For interface and DDC control panels:**

- a) Ensure devices are properly installed with adequate clearance for maintenance and with clear labels in accordance with the record drawings.
- b) Ensure that terminations are safe, secure and labeled in accordance with the record drawings.
- c) Check power supplies for proper voltage ranges and loading.
- d) Ensure that wiring and tubing are run in a neat and workman-like manner, either bound or enclosed in trough.
- e) Check for adequate signal strength on communication networks.
- f) Check for standalone performance of controllers by disconnecting the controller from the LAN. Verify that the controlling LAN reconfigures as specified in the event of a LAN disconnection.
- g) Ensure that all outputs and devices fail to their proper positions/states.
- h) Ensure that buffered and/or volatile information is held through power outage.
- i) Check for adequate grounding of all DDC panels and devices.

15. **For Operator Interfaces:**

- a) Verify that all elements on the LCS are functional and are properly bound to physical devices and/or virtual points.
- b) Verify that required third party software applications required with the bid are installed and are functional.

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

17. Verify proper interface with fire alarm system.

- B. **Submit Start-Up Test Report:** Report shall be completed, submitted, and approved prior to Substantial Completion.

III.2 SENSOR CHECKOUT AND CALIBRATION

- A. **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.

- B. **Calibration:** Calibrate all sensors using one of the following procedures:
1. 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.
 2. 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 the ammeter reads 4 mA. 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.
- C. **Sensor Tolerance:** Sensors shall be within the tolerances specified for the device. Refer to Section 230901.

III.3 COIL VALVE LEAK CHECK

- A. Verify proper close-off of the valves. Ensure the valve seats properly seat 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 Operator Interface, command the valve to close. Energize fans. After 5 minutes or longer, and the temperature is stable, 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.

III.4 VALVE STROKE SETUP AND CHECK

- A. For all valve and actuator positions checked, verify the actual position against the Operator Interface readout.
- B. 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 the valve to various few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics).

III.5 BAS DEMONSTRATION

- A. All BAS Demonstration shall take place on the Local Control Station (LCS) and UNC EMCS VLAN. Schedule to add system to LCS and UNC EMCS VLAN with the Owner at least 2 weeks in advance to the demonstration. At the time of request, provide all documentation that the following criteria are met:
 - 1. Updated BAS engineered drawings in hard and soft copies to Owner including the updated riser diagram for the system.
 - 2. Reports on verification of Network Layout Verification including but not limited to Building Controller locations, cable routes with length of cable between controllers and any trunk extenders or trunk isolators provided on as-built drawings.
 - 3. Reports on verification of electrical characteristics of BAS network, communications and electrical integrity of Building Controllers.
 - 4. Reports on verification of traffic on BAS Network and EMCS VLAN including but not limited to COVs between controllers, point commands by the operator, point commands by program across the network, alarm reporting on the network, any unresolved points in the system, and results of controller tests.
 - 5. Demonstrate to owner the updates of databases without errors or faults between the LCS and controllers.
- B. Demonstrate the operation of the BAS hardware, software, and all related components and systems to the satisfaction of the Commissioning Authority and Owner. Schedule the demonstration with the Owner's representative 2 weeks in advance. Demonstration shall not be scheduled until all hardware and software submittals, and the Start-Up Test Report are approved. If the Work fails to be demonstrated to conform to the Contract specifications, so as to require scheduling of additional site visits by the Commissioning Authority Owner for re-demonstration, Contractor shall reimburse Owner for costs of subsequent Commissioning Authority site visits.
- C. 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.
- D. Demonstration shall typically involve small representative samples of systems/equipment randomly selected by the Owner and CA.
- E. 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:
 - 1. Demonstrate that traffic on the ANSI 709.1 network does not exceed 30% bandwidth utilization by monitoring traffic with approved network analyzer during the remainder of these tests. The error rate for each channel shall not exceed 1%.
 - 2. Demonstrate that required software is installed on the LCS. Demonstrate that system screens are installed as submitted and approved. Demonstrate that points specified and shown can be interrogated and/or commanded (as applicable) from all workstations, as specified.

3. 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 the Commissioning Authority 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 Commissioning Authority 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.
 4. Demonstrate that all DDC and other software programs exist at respective field panels. The Direct Digital Control (DDC) programming, point database, and LNS shall be as submitted and approved.
 5. Demonstrate that all DDC programs accomplish the specified sequences of operation.
 6. Demonstrate that the panels automatically recover from power failures, as specified.
 7. 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.
 8. Identify access to equipment selected by Commissioning Authority] [by the Owner. Demonstrate that access is sufficient to perform required maintenance.
 9. Demonstrate that all required SNVTs have been bound to the BPOC and that the BPOC supports required EBMS functionality via WebServices.
- F. BAS Demonstration shall be completed and approved prior to Substantial Completion.
- G. Any tests successfully completed during the demonstration will be recorded as passed for the functional performance testing and will not have to be retested.

III.6 BAS ACCEPTANCE PERIOD

- A. After approval of the BAS Demonstration and prior to Contract Close Out Acceptance Phase shall commence. Acceptance Period shall not be scheduled until all HVAC systems are in operation and have been accepted, all required cleaning and lubrication has been performed.
- B. **Operational Test:** At the beginning of the Acceptance Phase, the system shall operate properly for two 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, contractor shall forward the trend logs to the Commissioning Authority/Owner for review. Commissioning Authority/Owner shall determine if the system is ready for functional performance testing and document any problems requiring contractor attention.
1. If the systems are not ready for functional performance testing, Contractor shall correct problems and provide notification to the Owner's 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 Commissioning Authority issues notice that the BAS is ready for functional performance testing.
- C. During the Acceptance Period, 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.

III.7 WARRANTY PHASE BAS OPPOSITE SEASON TRENDING AND TESTING:

- A. **Opposite Season Testing:** Within 12 months of completion of the Acceptance Phase, Commissioning Authority/Owner shall schedule and conduct Opposite Season functional performance testing. Contractor shall participate in this testing and remedy any deficiencies identified.

III.8 SOFTWARE OPTIMIZATION ASSISTANCE

- A. The Contractor shall provide the services of a BAS Technician as specified in Part 1 at the project site to be at the disposal of the Commissioning Authority/Owner. 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 Commissioning Authority/Owner 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, Commissioning Authority, and Owner. The Owner's representative shall notify contractor 2 days in advance of each day of requested assistance.
- B. The BAS Technician provided shall be thoroughly trained in the programming and operation of the controller. If the BAS Technician provided cannot perform every software task requested by the Commissioning Authority/Owner in a timely fashion, contractor shall provide additional qualified personnel at the project site as requested by the Commissioning Authority/Owner, to meet the total specified requirement on-site.

III.9 BAS OPERATOR TRAINING AND O&M MANUALS

- A. Provide up to 4 complete sets of the approved Operations and Maintenance (O&M) Manuals (hard copy and one electronic copy) to be used for training.
- B. Contractor shall submit a Training Plan for the scope of training for which (s)he is responsible. Training Plan shall be forwarded to the Division 15 Contractor who will compile, organize, format, and forward to the Engineer for review.
- C. **On-Site Training:** Provide services of controls contractor's qualified technical personnel for five 8-hour days to instruct Owner's personnel in operation and maintenance of 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 Engineer and Owner's representative for the purpose of discussing and fine-tuning the training agenda prior to the first training session. Training agenda shall generally be as follows:
 - 1. Basic LCS Training – For all potential users of the LCS:

- a) 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.
 - b) Brief overview of the various parts of the O&M Manuals, including hardware and software programming and operating publications, catalog data, controls installation drawings, and DDC programming documentation.
 - c) Demonstration of LCS login/logout procedures, password setup, and exception reporting.
 - d) Demonstration of LCS menu penetration and broad overview of the various workstation features.
 - e) Overview of systems installed.
 - f) Present all site-specific point naming conventions and points lists, open protocol information, configuration databases, back-up sequences, upload/download procedures, and other information as necessary to maintain the integrity of the BAS.
 - g) Overview of the Sequence of Operation for all systems
 - h) Overview of LCS reports.
2. BAS Hardware Training – For Maintenance and Control Technicians
- a) Review of installed components and how to install/replace, maintain, commission, and diagnose them
3. BAS Technician Training:
- a) Introduction to controller programming and overview of the programming application interface.
 - b) General review of sequence of operation and control logic for the project site, including standalone and fail-safe modes of operation.
 - c) Uploading/Downloading and backing up programs.
 - d) Network administration.
 - e) Review of setpoint optimization and fine-tuning concepts.

*AE shall consult with UNC to determine if the Off-Site Training is required for the project.
Edit accordingly*

D. Off-Site Advanced Training:

- 1. Two week Advanced Training shall be provided at any time during the warranty period for two individuals and be provided at the manufacturer's off-site training facility containing installations of the proposed system. Contractor shall pay training registration, materials, and miscellaneous fees. The Owner shall pay for all expenses for travel (travel, transportation, meals, lodging, etc.).
 - a) Advance training shall include the standard, advanced training offering on all Control Programming Applications for the system installed.
 - b) Advance training shall include the standard, advanced training offering on Advanced Installation, Configuration, Maintenance, and Network Administration.

END OF SECTION 230801