PART I. GENERAL

1.01 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

1.02 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 15950 – BAS General Requirements
C. Section 23 0900 - BAS General Requirements
D. Section 15951 - BAS Basic Materials, Interface Devices and Sensors
E. Section 23 0913 – BAS Basic Materials, Interface Devices, and Sensors
F. Section 15952 - BAS Operator Interfaces
G. Section 23 0902 - BAS Operator Interfaces
H. Section 15953 - BAS Field Panels
I. Section 23 0903 - BAS Field Panels
J. Section 15954 - BAS Communication Devices
K. Section 23 0904 - BAS Communication Devices
L. Section 15955 - BAS Software and Programming
M. Section 23 0905 - BAS Software and Programming
N. Section 15958 - Sequence of Operation
O. Section 23 0993 - Sequences of Operation

1.03 GENERAL DESCRIPTION

A. This section defines responsibilities of the Controls Contractor to commission the BAS.

*Edit this to clarify whether there is a formal Cx process and indicate responsibilities.*

B. Refer to Section 01800 for an overview of the commissioning process, entities involved in the process, training requirements, start-up requirements, and requirements for functional performance testing.

*The following is written based on the use of a separate Commissioning Authority (CA). If that is not the case on the project, the Contractor must still start up and commission the BAS. Therefore edit the responsibilities as appropriate for the project commissioning requirements.*
1.04 CONTRACTOR RESPONSIBILITIES

A. Completely install and thoroughly inspect, startup, test, adjust, balance, and document all systems and equipment.

B. [Assist Commissioning Authority in] Perform verification and performance testing. This will generally include the following:
   1. [Attend Commissioning (Cx) progress and coordination meetings.]
   2. [Prepare and submit required draft forms and systems information.]
   3. 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 University’s Representatives as specified in Part III of this section.

The following two items only apply to formal commissioning processes. Edit as applicable.

C. Provide a BAS Technician to work at the direction of Commissioning Authority for software optimization assistance for a minimum of [80] hours for Scope 1 and [40] hours for Scope 2. Refer to Part 3 for a description of the software optimization.

Edit the following to suit the program and application.

1.05 SUBMITTALS

A. Submit the following Quality Assurance / Quality Control documentation directly to UCB [and the CA]:
   1. Quality Assurance Plan
      a) Contractor must provide a description of their quality assurance operations for the commissioning phase of this project. The description shall include protocols for each step of commissioning listed within this section including testing, reporting, coordination with the CA and remediation of all action items.

B. Submit the following items directly to the [CA] [GC]:
   1. BAS Start-Up Report (reference div. 1 and section 3.01 below): Submit four (4) copies prior to scheduling of Functional Performance Testing.
   2. BAS Training Plan (defined below): Submit prior to scheduling BAS Demonstration.
   3. Trend and alarm logs as required during the Acceptance Period and Warranty Period.

PART II. PART 2 - PRODUCTS

2.01 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 12-month period. Certificates of calibration shall be made available when requested.
PART III. PART 3 – EXECUTION

*Edit the following to suit the application.*

3.01 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.

4. 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 portable 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, wireless, or at the thermostat). 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. Record the measured value and displayed value for each device in the BAS Start Up Report.

6. Check and set zero and span adjustments for all transducers and transmitters. Excessive signal buffering is not acceptable, span adjustments must be within 2% of their respective end points. (i.e. Do not control a 2-10vdc actuator with a 0-10vdc signal; worst case signal should be 1.8-10.2vdc.)

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.]

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.

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 Start Up 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: ±1°F.
   b) Space Temperature: ±2°F
   c) Chilled Water: ±1°F
   d) Hot water temperature: ±3°F.
   e) Duct pressure: ±0.25” w.g.
   f) Water pressure: ±1 psid
   g) Duct or space Humidity: ±5%
   h) Air flow control: ±5% of setpoint velocity.
   i) Space Pressurization (on active control systems): ±0.05” wg with no door or window movements.

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 the event is annunciated at Operator Interfaces. 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) With all system and communications operating normally, sample and record update/annunciation times for critical alarms fed from the panel to the Operator Interface.

j) Check for adequate grounding of all DDC panels and devices.

k) Thoroughly clean interior and exterior of control panel per manufacturer’s instructions.

15. For Operator Interfaces:

a) 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.

b) Output all specified BAS reports for review and approval.

c) Verify that the alarm printing and logging is functional and per requirements.

d) Verify that trends are archiving to disk and provide a sample to the [Commissioning Authority and] University for review.

e) Verify that paging/dial-out alarm annunciation is functional.

f) Verify the functionality of remote Operator Interfaces and that a robust connection can be established consistently.

g) 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.

3.02 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 15951.

### 3.03 COIL VALVE LEAK CHECK

A. 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 Operator Interface, 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.

### 3.04 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).

### 3.05 BAS DEMONSTRATION

A. Demonstrate the operation of the BAS hardware, software, and all related components and systems to the satisfaction of the [Commissioning Authority and] University. Schedule the demonstration with the University’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. If the Work fails to be demonstrated to conform with Contract specifications, so as to require scheduling of additional site visits by the [Commissioning Authority] University for re-demonstration, Contractor
shall reimburse University for costs of subsequent [Commissioning Authority] site visits.

B. 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.

C. Demonstration shall typically involve small representative samples of systems/equipment randomly selected by the University [and CA].

D. 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 required software is installed on BAS workstations. Demonstrate that graphic screens, alarms, trends, and reports are installed as submitted and approved.

   2. Demonstrate that points specified and shown can be interrogated and/or commanded (as applicable) from all workstations, as specified.

   3. Demonstrate that remote communication abilities are in accordance with these Specifications.

   4. 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] University 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.

   5. Demonstrate that all DDC and other software programs exist at respective field panels. The Direct Digital Control (DDC) programming and point database shall be as submitted and approved.

   6. Demonstrate that all DDC programs accomplish the specified sequences of operation.

   7. Demonstrate that the panels automatically recover from power failures, as specified.

   8. 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.

   9. Identify access to equipment selected [by Commissioning Authority] [by the University]. Demonstrate that access is sufficient to perform required maintenance.

   10. Demonstrate that required trend graphs and trend logs are set up per the requirements.

E. BAS Demonstration shall be completed and approved prior to Substantial Completion.

F. Any tests successfully completed during the demonstration will be recorded as passed for the functional performance testing and will not have to be retested.
3.06 TREND LOGS
   A. Contractor shall configure and analyze all trends required under Section 15955.  
      The following item only applies to a formal Cx process.

3.07 WARRANTY PERIOD:
   A. Warranty Period shall not commence until successful completion of the BAS Demonstration.
   B. Trending: Throughout the Warranty Period, trend logs shall be maintained.  
      Contractor shall forward archive trend logs to the Commissioning Authority/University for review upon Commissioning Authority/University request. Commissioning Authority/University will review these and notify contractor of any warranty work required.
   C. Opposite Season Testing: Within 6 months of completion of the Acceptance Phase,  
      Commissioning Authority/University shall schedule and conduct Opposite Season functional performance testing. Contractor shall participate in this testing and remedy any deficiencies identified
   D. End of Warranty Visit: Commissioning Authority/University will conduct an End of Warranty walkthrough prior to the end of the Warranty Period. Contractor shall participate in this walkthrough and remedy any deficiencies identified.

3.08 SOFTWARE OPTIMIZATION ASSISTANCE
   A. The Contractor shall provide the services of a BAS Technician as specified above at the project site to be at the disposal of the [Commissioning Authority/] University. 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/] University 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 University. The University’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 and workstation software. If the BAS Technician provided cannot perform every software task requested by the [Commissioning Authority/] University in a timely fashion, contractor shall provide additional qualified personnel at the project site as requested by the [Commissioning Authority/] University, to meet the total specified requirement on-site.

3.09 BAS OPERATOR TRAINING AND O&M MANUALS
   A. Contractor shall submit a Training Plan for the scope of training for which they are responsible. Training Plan shall be forwarded to the Division 15 Contractor who will compile, organize, format, and forward to the Engineer for review.
   B. On-Site Training: Provide services of controls contractor’s qualified technical personnel for [five] 8-hour days to instruct University’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 University. The University’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 University’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 Operator Workstation (OWS) Training** – For all potential users of the OWS:
   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 workstation login/logout procedures, password setup, and exception reporting.
   d) Demonstration of workstation 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 alarm features.
   h) Overview of trend features.
   i) Overview of workstation 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.

*The following item must be coordinated with UCB with regard to applicability and cost.*

4. **Advanced Training**: Advanced Training shall be provided for [two] individuals and be provided at an off-site training facility containing installations of the proposed system. Contractor shall pay training registration and materials fee and the University shall pay all employee expenses (travel, per diem, salary).
   a) Contractor shall provide the standard, advanced training offering on all Control Programming Applications.
   b) Contractor shall provide the standard, advanced training offering on Advanced Installation, Configuration, Maintenance, and Network Administration.