SECTION 230923 - DIRECT DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

B. Refer to Specification Section 230800 “Mechanical, Electrical and Plumbing Systems Commissioning for required coordination with the Commissioning Authority.

C. The controls contractor shall provide assistance to the Commissioning Authority during the commissioning process.

1.2 SUMMARY

A. Section Includes:

1. DDC system for monitoring and controlling of HVAC systems.
2. Delivery of selected control devices to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.

1.3 WORK DESCRIPTION

A. The Building Management System (BMS) shall perform both monitoring and control of mechanical and electrical equipment for building management, energy conservation, and environmental control.

B. The BMS control philosophy shall be direct digital control and be implemented by a distributed digital system.

C. A personal computer (PC) shall provide for overall building data acquisition and transfer, report generation, historical data storage and retrieval, and operator interface. Location of PC shall be in building engineer’s office.

D. The PC and DDCs shall communicate through dedicated communications network(s). All communications on network shall be by digital signals only.

E. Operator’s workstation shall as minimum support Point-to-Point (PTP) and Ethernet LAN types.

F. The Direct Digital Controllers shall perform remote data acquisition and process control. DDC panels shall be locally mounted completely capable of stand alone operation.

G. Each DDC shall be connected to its particular controlled environment through field input/output (I/O) instrumentation.
H. The BMS system shall be BACNet protocol

I. The BMS shall be web accessible.

J. Expansion Capability:
   1. System Point Capacity. The system shall be expandable to at least twice the number of input/output objects required for this project. Additional controllers (along with associated devices and wiring) shall be all that is necessary to achieve this capacity requirement. The PC operator interfaces installed for this project shall not require any hardware additions or software revisions in order to expand the system.

K. System shall be modular to allow change of function and operation in the field by plug-in modules, equipment and software changes to expand system capacity without interrupting system operation.

1.4 SUBMITTALS

A. Multiple Submissions:
   1. If multiple submissions are required to execute work within schedule, first submit a coordinated schedule clearly defining intent of multiple submissions. Include a proposed date of each submission with a detailed description of submittal content to be included in each submission.
   2. Clearly identify each submittal requirement indicated and in which submission the information will be provided.
   3. Include an updated schedule in each subsequent submission with changes highlighted to easily track the changes made to previous submitted schedule.

B. Product Data: For each type of product include the following:
   1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
   2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
   4. Installation, operation and maintenance instructions including factors effecting performance.
   5. Bill of materials of indicating quantity, manufacturer, and extended model number for each unique product.
      a. DDC controllers.
      b. Enclosures.
      c. Electrical power devices.
      d. Accessories.
      e. Instruments.
      f. Control dampers and actuators.
      g. Control valves and actuators.
6. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.

7. Each submitted piece of product literature shall clearly cross reference specification and drawings that submittal is to cover.

C. Shop Drawings:

1. General Requirements:
   a. Include cover drawing with Project name, location, Owner, Architect, Contractor and issue date with each Shop Drawings submission.
   b. Include a drawing index sheet listing each drawing number and title that matches information in each title block.

2. Include plans, elevations, sections, and mounting details where applicable.

3. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

4. Plan Drawings indicating the following:
   a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork and piping.
   b. Room names and numbers with coordinated placement to avoid interference with control products indicated.
   c. Each desktop workstation, server, gateway, router, DDC controller, control panel instrument connecting to DDC controller, and damper and valve connecting to DDC controller, if included in Project.
   d. Exact placement of products in rooms, ducts, and piping to reflect proposed installed condition.
   e. Network communication cable and raceway routing.
   f. Information, drawn to scale.
   g. Proposed routing of wiring, cabling, conduit, and tubing, coordinated with building services for review before installation.

5. Schematic drawings for each controlled HVAC system indicating the following:
   a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
   b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.
   c. A graphic showing location of control I/O in proper relationship to HVAC system.
   d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
   e. Unique identification of each I/O that shall be consistently used between different drawings showing same point.
   f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays and interface to DDC controllers.
   g. Narrative sequence of operation.
   h. Graphic sequence of operation, showing all inputs and output logical blocks.
6. Control panel drawings indicating the following:
   a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
   b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates and allocated spare space.
   c. Front, rear, and side elevations and nameplate legend.
   d. Unique drawing for each panel.

7. DDC system network riser diagram indicating the following:
   a. Each device connected to network with unique identification for each.
   b. Interconnection of each different network in DDC system.
   c. For each network, indicate communication protocol, speed and physical means of interconnecting network devices, such as copper cable type, or optical fiber cable type. Indicate raceway type and size for each.
   d. Each network port for connection of an operator workstation or other type of operator interface with unique identification for each.

8. DDC system electrical power riser diagram indicating the following:
   a. Each point of connection to field power with requirements (volts/phase/hertz/amperes/connection type) listed for each.
   b. Each control power supply including, as applicable, transformers, power-line conditioners, transient voltage suppression and high filter noise units, DC power supplies, and UPS units with unique identification for each.
   c. Each product requiring power with requirements (volts/phase/hertz/amperes/connection type) listed for each.
   d. Power wiring type and size, race type, and size for each.

9. Monitoring and control signal diagrams indicating the following:
   a. Control signal cable and wiring between controllers and I/O.
   b. Point-to-point schematic wiring diagrams for each product.
   c. Control signal tubing to sensors, switches and transmitters.
   d. Process signal tubing to sensors, switches and transmitters.

10. Color graphics indicating the following:
    a. Itemized list of color graphic displays to be provided.
    b. For each display screen to be provided, a true color copy showing layout of pictures, graphics and data displayed.
    c. Intended operator access between related hierarchical display screens.

D. System Description:

1. Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.
2. Complete listing and description of each report, log and trend for format and timing and events which initiate generation.
3. System and product operation under each potential failure condition including, but not limited to, the following:
   a. Loss of power.
   b. Loss of network communication signal.
   c. Loss of controller signals to inputs and outputs.
   d. Operator workstation failure.
   e. Server failure.
   f. Gateway failure.
   g. Network failure.
   h. Controller failure.
   i. Instrument failure.
   j. Control damper and valve actuator failure.
   k. Description of Owner training.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For DDC system to include in emergency, operation and maintenance manuals.

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:

   a. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.
   b. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
   c. As-built versions of submittal Product Data.
   d. Names, addresses, e-mail addresses and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
   e. Operator's manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control and changing set points and variables.
   f. Programming manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
   g. Engineering, installation, and maintenance manuals that explain how to:
      1) Design and install new points, panels, and other hardware.
      2) Perform preventive maintenance and calibration.
      3) Debug hardware problems.
      4) Repair or replace hardware.
   h. Documentation of all programs created using custom programming language including set points, tuning parameters, and object database.
   i. Backup copy of graphic files, programs, and database on electronic media such as DVDs.
   j. List of recommended spare parts with part numbers and suppliers.
   k. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
l. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
m. Licenses, guarantees, and warranty documents.
n. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
o. Owner training materials.

1.6 WARRANTY

A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period.

1. Failures shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.
   a. Install updates only after receiving Owner's written authorization.
3. Warranty Period: Two year(s) from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 DDC SYSTEM MANUFACTURERS

A. Manufacturers:
   1. Trane.

2.2 DDC SYSTEM DESCRIPTION

A. Microprocessor-based monitoring and control including analog/digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices to achieve a set of predefined conditions.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 DDC SYSTEM OPERATOR INTERFACES

A. Operator Means of System Access: Operator shall be able to access entire DDC system through any of multiple means, including, but not limited to, the following:

   1. Desktop and portable workstation with hardwired connection through LAN port.
   2. Portable operator terminal with hardwired connection through LAN port.
3. Portable operator workstation with wireless connection through LAN router.
4. Mobile device and application with secured wireless connection through LAN router or cellular data service.

B. Access to system, regardless of operator means used, shall be transparent to operator.

2.4 DDC CONTROLLERS

A. DDC system shall consist of a combination of network controllers, programmable application controllers and application-specific controllers to satisfy performance requirements indicated.

B. DDC controllers shall perform monitoring, control, energy optimization and other requirements indicated.

C. DDC controllers shall use a multitasking, multiuser, real-time digital control microprocessor with a distributed network database and intelligence.

D. Each DDC controller shall be capable of full and complete operation as a completely independent unit and as a part of a DDC system wide distributed network.

E. Environment Requirements:

1. Controller hardware shall be suitable for the anticipated ambient conditions.

2.5 NETWORK CONTROLLERS

A. General Network Controller Requirements:

1. Include adequate number of controllers to achieve performance indicated.
2. System shall consist of one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.
3. Controller shall have enough memory to support its operating system, database, and programming requirements.
4. Data shall be shared between networked controllers and other network devices.
5. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
6. Controllers that perform scheduling shall have a real-time clock.
7. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
8. Controllers shall be fully programmable.

B. Communication:

1. Network controllers shall communicate with other devices on DDC system Level one network.
2. Network controller also shall perform routing if connected to a network of programmable application and application-specific controllers.
2.6 PROGRAMMABLE APPLICATION CONTROLLERS

A. General Programmable Application Controller Requirements:

1. Include adequate number of controllers to achieve performance indicated.
2. Controller shall have enough memory to support its operating system, database, and programming requirements.
3. Data shall be shared between networked controllers and other network devices.
4. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
5. Controllers that perform scheduling shall have a real-time clock.
6. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
7. Controllers shall be fully programmable.

B. Communication:

1. Programmable application controllers shall communicate with other devices on network.

2.7 CONTROL DAMPERS

A. Motorized dampers, unless otherwise specified elsewhere, shall meet the following:

1. Damper frames shall use 12 or 13 gauge galvanized steel channel or 1/8" extruded aluminum with reinforced corner bracing.
2. The damper blades shall not exceed eight (8) inches in width or 48" in length.
3. Damper bearings shall be oil-impregnated sintered bronze or bearing grade nylon. Bushings that turn in the bearing are to be oil impregnated sintered metal.
4. All blade edges and top and bottom of the frame shall be provided with replaceable, butyl rubber or neoprene seals. Side seals shall be spring-loaded stainless steel, synthetic elastomer, or combinations of both. The seals shall provide a maximum leakage rate of 1/2% of maximum flow or 10 CFM/SF leakage at 4" W.C. close-off pressure.
5. The damper linkage shall be concealed and provide a linear flow or equal percentage characteristic as required.
6. Dampers shall be airfoil type dampers.
7. Provide a minimum of one damper actuator per damper section.

B. Unless otherwise scheduled, the control dampers for outdoor/return air mixing box dampers shall be parallel blade, arranged to direct air streams towards each other. Dampers used for air volume or pressure control modulating applications shall be opposed blade type. All other dampers may be parallel or opposed blade type.

2.8 ELECTRONIC ACTUATORS

A. General:

1. Actuators shall be of the magnetic or electronic type with linear or rotary actuation for proportional modulating, 3-point floating, or 2-position control as required by the application.
2. The electronic actuators shall use an overload-proof synchronous motor or an electric motor with end switches to de-energize the motor at the end of the stroke limits.
3. Control voltage shall be 24VAC, 0-20VDC, 0-10VDC, or 4-20mA as required.
4. All damper applications with outdoor air openings shall be provided with spring return to the closed position.
5. All actuator torque ratings shall be 150% of the requirements of the application.

2.9 AIR FLOW MONITORING STATIONS

A. Air flow stations shall be manufactured by Air Monitor, or approved equivalent.

B. Provide on the indicated fans, Airflow Measuring System(s) mounted in the fan inlets capable of continuously measuring the air handling capacity (air volume) of the respective centrifugal fan(s). Each Airflow Measuring System shall consist of an Airflow Measuring Station and a Transmitter. In order guarantee the overall accuracy and performance of the Airflow Measuring System, the Airflow Measuring Station and the Transmitter shall be by the same manufacturer.

C. Airflow Measuring Station (VOLU-probe/FI – Fan Inlet Airflow Traverse Probe):
   1. The Airflow Measuring Station shall contain multiple total and static pressure sensors placed at concentric area centers along the exterior surface of the cylindrical probes and internally connected to their respective averaging manifolds. Sensors shall not protrude beyond the surface of the probe, nor be adversely affected by particle contamination normally present in building system airflows.
   2. The Airflow Measuring Station shall have symmetrical averaging signal takeoffs, and shall be of aluminum construction with hard anodized finish [copper construction] with galvanized steel mounting hardware.
   3. The Airflow Measuring Station shall not significantly impact fan performance or contribute to fan generated noise levels. The probes shall be capable of producing steady, non-pulsating signals of standard total and static pressure, without need for flow corrections or factors, with an accuracy of 3% of actual flow over a fan operating range of 6 to 1 capacity turndown.

D. Transmitter:
   1. Transmitter (VELTRON II Microprocessor Based Pressure & Flow “Smart” Transmitter).
   2. The Transmitter shall be capable of receiving flow signals (total and static pressure) from an airflow station or probe array and produce dual outputs linear and scaled for air volume, velocity, differential pressure, etc.
   3. The Transmitter shall contain an integral multi-line digital display for use during the configuration and calibration process, and to display one transmitter output during normal operating mode. All Transmitter configuration, parameter setting, zero and span calibration, plus display formatting and scaling will be performed digitally in the on-board microprocessor via input pushbuttons.
   4. The Transmitter will be available in multiple natural spans covering the range of 0.05 IN w.c. to 10.0 IN w.c. with an accuracy of 0.1% of natural span. The Transmitter shall be furnished with a transducer automatic zeroing circuit and be capable of maintaining linear output signals on applications requiring 10 to 1 velocity (100 to 1 pressure) turndown.
   5. Transmitter shall be capable of having its operating span electronically selected without having to perform recalibration involving an external pressure source.
E. Space Mounted Temperature Sensors:
   1. Temperature sensors shall be linear precision elements with ranges appropriate for their applications.
   2. Temperature sensors shall consist of a sensing element attached to the back of a stainless steel wall plate.

F. Space Mounted Indoor Air Quality Sensors:
   1. Air quality sensor shall be capable of monitoring multiple types of carbon-based air contaminants, volatile organic compounds and carbon dioxide.
   2. The sensor shall monitor the aggregate of the contaminants to produce a relative air quality reading of 0 to 10 VDC signal.
   3. The air quality sensor shall be space mounted.
   4. Approved manufacturers:
      a. Siemens QPA63 series, or approved equivalent.
   5. Sensors that measure carbon dioxide only are not acceptable.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
   1. Verify compatibility with and suitability of substrates.

B. Examine roughing-in for products to verify actual locations of connections before installation.
   1. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
   2. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.

C. Examine walls, floors, roofs, and ceilings for suitable conditions where product will be installed.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 GENERAL INSTALLATION REQUIREMENTS

A. Install products to satisfy more stringent of all requirements indicated.

B. Install products level, plumb, parallel, and perpendicular with building construction.

C. Support products, tubing, piping wiring and raceways.

D. If codes and referenced standards are more stringent than requirements indicated, comply with requirements in codes and referenced standards.
E. Fabricate openings and install sleeves in ceilings, floors, roof, and walls required by installation of products. Before proceeding with drilling, punching, and cutting, check for concealed work to avoid damage. Patch, flash, grout, seal, and refinish openings to match adjacent condition.

F. If product locations are not indicated, install products in locations that are accessible and that will permit service and maintenance from floor, equipment platforms, or catwalks without removal of permanently installed furniture and equipment.

3.3 CONTROLLER INSTALLATION

A. Install controllers in enclosures to comply with indicated requirements.

B. Connect controllers to field power supply.

C. Install controller with latest version of applicable software and configure to execute requirements indicated.

D. Test and adjust controllers to verify operation of connected I/O to achieve performance indicated requirements while executing sequences of operation.

E. Installation of Network Controllers:
   1. Quantity and location of network controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
   2. Install controllers in a protected location that is easily accessible by operators.

F. Installation of Programmable Application Controllers:
   1. Quantity and location of programmable application controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
   2. Install controllers in a protected location that is easily accessible by operators.

G. Application-Specific Controllers:
   1. Quantity and location of application-specific controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
   2. For controllers not mounted directly on equipment being controlled, install controllers in a protected location that is easily accessible by operators.

3.4 ELECTRIC POWER CONNECTIONS

A. Connect electrical power to DDC system products requiring electrical power connections.

B. Design of electrical power to products not indicated with electric power is delegated to DDC system provider and installing trade. Work shall comply with NFPA 70 and other requirements indicated.
3.5 **CONTROL WIRE, CABLE AND RACEWAYS INSTALLATION**

A. Comply with NECA 1.

3.6 **DDC SYSTEM I/O CHECKOUT PROCEDURES**

A. Check installed products before continuity tests, leak tests and calibration.

B. Check instruments for proper location and accessibility.

C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.

D. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material and support.

3.7 **DDC SYSTEM I/O ADJUSTMENT, CALIBRATION AND TESTING:**

A. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.

B. Equipment and procedures used for calibration shall comply with instrument manufacturer's written instructions.

C. Provide diagnostic and test equipment for calibration and adjustment.

D. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. An installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.

E. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.

F. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.

G. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.

H. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

I. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact making or breaking.

J. Control Dampers:

1. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
2. Stroke control dampers with pilot positioners. Adjust damper and positioner following manufacturer's recommended procedure, so damper is 100 percent closed, 50 percent closed and 100 percent open at proper air pressure.
3. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
4. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

K. Control Valves:

1. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
2. Stroke control valves with pilot positioners. Adjust valve and positioner following manufacturer's recommended procedure, so valve is 100 percent closed, 50 percent closed and 100 percent open at proper air pressures.
3. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
4. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

L. Meters: Check sensors at zero, 50, and 100 percent of Project design values.

M. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

N. Switches: Calibrate switches to make or break contact at set points indicated.

O. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistant source.

3.8 DDC SYSTEM CONTROLLER CHECKOUT

A. Verify power supply:

1. Verify voltage, phase and hertz.
2. Verify that protection from power surges is installed and functioning.
3. Verify that ground fault protection is installed.
4. If applicable, verify if connected to UPS unit.
5. If applicable, verify if connected to a backup power source.
6. If applicable, verify that power conditioning units, transient voltage suppression and high-frequency noise filter units are installed.
B. Verify that wire and cabling is properly secured to terminals and labeled with unique identification.

C. Verify that spare I/O capacity is provided.

3.9 DDC CONTROLLER I/O CONTROL LOOP TESTS

A. Testing:

1. Test every I/O point connected to DDC controller to verify that safety and operating control set points are as indicated and as required to operate controlled system safely and at optimum performance.
2. Test every I/O point throughout its full operating range.
3. Test every control loop to verify operation is stable and accurate.
4. Adjust control loop proportional, integral and derivative settings to achieve optimum performance while complying with performance requirements indicated. Document testing of each control loop's precision and stability via trend logs.
5. Test and adjust every control loop for proper operation according to sequence of operation.
6. Test software and hardware interlocks for proper operation. Correct deficiencies.
7. Operate each analog point at the following:
   a. Upper quarter of range.
   b. Lower quarter of range.
   c. At midpoint of range.
8. Exercise each binary point.
9. For every I/O point in DDC system, read and record each value at operator workstation, at DDC controller and at field instrument simultaneously. Value displayed at operator workstation, at DDC controller and at field instrument shall match.
10. Prepare and submit a report documenting results for each I/O point in DDC system and include in each I/O point a description of corrective measures and adjustments made to achieve desired results.

3.10 DDC SYSTEM VALIDATION TESTS

A. Perform validation tests before requesting final review of system. Before beginning testing, first submit Pretest Checklist and Test Plan.

B. After approval of Test Plan, execute all tests and procedures indicated in plan.

C. After testing is complete, submit completed test checklist.

D. Pretest Checklist: Submit the following list with items checked off once verified:

1. Detailed explanation for any items that are not completed or verified.
2. Required mechanical installation work is successfully completed and HVAC equipment is working correctly.
3. HVAC equipment motors operate below full-load amperage ratings.
4. Required DDC system components, wiring, and accessories are installed.
5. Installed DDC system architecture matches approved Drawings.
6. Control electric power circuits operate at proper voltage and are free from faults.
7. Required surge protection is installed.
8. DDC system network communications function properly, including uploading and downloading programming changes.
9. Using BACnet protocol analyzer, verify that communications are error free.
10. Each controller's programming is backed up.
11. Equipment, products, tubing, wiring cable and conduits are properly labeled.
12. All I/O points are programmed into controllers.
13. Testing, adjusting and balancing work affecting controls is complete.
14. Dampers and actuators zero and span adjustments are set properly.
15. Each control damper and actuator goes to failed position on loss of power.
16. Valves and actuators zero and span adjustments are set properly.
17. Each control valve and actuator goes to failed position on loss of power.
18. Meter, sensor and transmitter readings are accurate and calibrated.
19. Control loops are tuned for smooth and stable operation.
20. View trend data where applicable.
21. Each controller works properly in standalone mode.
22. Safety controls and devices function properly.
23. Interfaces with fire-alarm system function properly.
24. Electrical interlocks function properly.
25. Operator workstations and other interfaces are delivered, all system and database software is installed, and graphic are created.
26. Record Drawings are completed.

E. Test Plan:

1. Prepare and submit a validation test plan including test procedures for performance validation tests.
2. Test plan shall address all specified functions of DDC system and sequences of operation.
3. Explain detailed actions and expected results to demonstrate compliance with requirements indicated.
4. Explain method for simulating necessary conditions of operation used to demonstrate performance.
5. Include a test checklist to be used to check and initial that each test has been successfully completed.
6. Submit test plan documentation 20 business days before start of tests.

F. Validation Test:

1. Verify operating performance of each I/O point in DDC system.
   a. Verify analog I/O points at operating value.
   b. Make adjustments to out-of-tolerance I/O points.

      1) Identify I/O points for future reference.
      2) Simulate abnormal conditions to demonstrate proper function of safety devices.
      3) Replace instruments and controllers that cannot maintain performance indicated after adjustments.
2. Simulate conditions to demonstrate proper sequence of control.
3. Readjust settings to design values and observe ability of DDC system to establish desired conditions.
4. Completely check out, calibrate, and test all connected hardware and software to ensure that DDC system performs according to requirements indicated.
5. After validation testing is complete, prepare and submit a report indicating all I/O points that required correction and how many validation re-tests it took to pass. Identify adjustments made for each test and indicate instruments that were replaced.

3.11 MAINTENANCE SERVICE

A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include 12 months' full maintenance by DDC system manufacturer's authorized service representative.

3.12 DEMONSTRATION

A. Engage a factory-authorized service representative with complete knowledge of Project-specific system installed to train Owner's maintenance personnel to adjust, operate, and maintain DDC system.

B. Extent of Training:

1. Base extent of training on scope and complexity of DDC system indicated and training requirements indicated. Provide extent of training required to satisfy requirements indicated even if more than minimum training requirements are indicated.
2. Inform Owner of anticipated training requirements if more than minimum training requirements are indicated.
3. Minimum Training Requirements:

   a. Provide not less than one (1) day of training total.

END OF SECTION 230923