

## SECTION 230923 - DIRECT DIGITAL CONTROL (DDC) 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.

## 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 PRE-INSTALLATION MEETINGS

- A. Pre-installation Conference: Conduct conference at **Project site**.

## 1.4 ACTION SUBMITTALS

- A. 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.
  - 3. Product description with complete technical data, performance curves, and product specification sheets.
  - 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. Workstations.
    - b. Servers.
    - c. Printers.
    - d. Gateways.
    - e. Routers.
    - f. Protocol analyzers.
    - g. DDC controllers.
    - h. Enclosures.
    - i. Electrical power devices.
    - j. UPS units.
    - k. Accessories.

- l. Instruments.
    - m. Control dampers and actuators.
    - n. 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.
- B. Software Submittal:
1. Cross-referenced listing of software to be loaded on each operator workstation, server, gateway, and DDC controller.
  2. Description and technical data of all software provided, and cross-referenced to products in which software will be installed.
  3. Operating system software, operator interface and programming software, color graphic software, DDC controller software, maintenance management software, and third-party software.
  4. Include a flow diagram and an outline of each subroutine that indicates each program variable name and units of measure.
  5. Listing and description of each engineering equation used with reference source.
  6. Listing and description of each constant used in engineering equations and a reference source to prove origin of each constant.
  7. Description of operator interface to alphanumeric and graphic programming.
  8. Description of each network communication protocol.
  9. Description of system database, including all data included in database, database capacity and limitations to expand database.
  10. Description of each application program and device drivers to be generated, including specific information on data acquisition and control strategies showing their relationship to system timing, speed, processing burden and system throughout.
  11. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.
- 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, and required clearances, method of field assembly, components, and location and size of each field connection.
  4. Detail means of vibration isolation and show attachments to rotating equipment.
  5. 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. Proposed routing of wiring, cabling, conduit, and tubing, coordinated with building services for review before installation.
6. 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.
7. 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.
8. 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.
9. 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.
10. 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.
11. 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.
  4. Complete bibliography of documentation and media to be delivered to Owner.
  5. Description of testing plans and procedures.
  6. Description of Owner training.
- E. Delegated-Design Submittal: For DDC system products and installation indicated as being delegated.

1. Supporting documentation showing DDC system design complies with performance requirements indicated, including calculations and other documentation necessary to prove compliance.
2. Schedule and design calculations for control dampers and actuators.
  - a. Flow at Project design and minimum flow conditions.
  - b. Face velocity at Project design and minimum airflow conditions.
  - c. Pressure drop across damper at Project design and minimum airflow conditions.
  - d. AMCA 500-D damper installation arrangement used to calculate and schedule pressure drop, as applicable to installation.
  - e. Maximum close-off pressure.
  - f. Leakage airflow at maximum system pressure differential (fan close-off pressure).
  - g. Torque required at worst case condition for sizing actuator.
  - h. Actuator selection indicating torque provided.
  - i. Actuator signal to control damper (on, close or modulate).
  - j. Actuator position on loss of power.
  - k. Actuator position on loss of control signal.
3. Schedule and design calculations for control valves and actuators.
  - a. Flow at Project design and minimum flow conditions.
  - b. Pressure-differential drop across valve at Project design flow condition.
  - c. Maximum system pressure-differential drop (pump close-off pressure) across valve at Project minimum flow condition.
  - d. Design and minimum control valve coefficient with corresponding valve position.
  - e. Maximum close-off pressure.
  - f. Leakage flow at maximum system pressure differential.
  - g. Torque required at worst case condition for sizing actuator.
  - h. Actuator selection indicating torque provided.
  - i. Actuator signal to control damper (on, close or modulate).
  - j. Actuator position on loss of power.
  - k. Actuator position on loss of control signal.
4. Schedule and design calculations for selecting flow instruments.
  - a. Instrument flow range.
  - b. Project design and minimum flow conditions with corresponding accuracy, control signal to transmitter and output signal for remote control.
  - c. Extreme points of extended flow range with corresponding accuracy, control signal to transmitter and output signal for remote control.
  - d. Pressure-differential loss across instrument at Project design flow conditions.
  - e. Where flow sensors are mated with pressure transmitters, provide information for each instrument separately and as an operating pair.

#### 1.5 INFORMATIONAL SUBMITTALS

- A. Source quality-control reports.
- B. Field quality-control reports.
- C. Sample Warranty: For manufacturer's warranty.

## 1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For DDC system to include in emergency, operation and maintenance manuals.
  - 1. 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.

## 1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
- B. Include product manufacturers' recommended parts lists for proper product operation over **four**-year period following warranty period. Parts list shall be indicated for each year.

## 1.8 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. As part of the 1st year warranty period the automatic control system contractor shall provide 24/7/365 monitoring up to 60 of the most critical alarms as coordinated with the owner from a dedicated remote facility staffed with HVAC technical specialist.
  2. To guarantee continual monitoring, communication between the remote monitoring facility and the bas must be tested and proven each quarter. A record of this successful test, as well as a record of each automated critical alarm recorded and sent to owner, must also be delivered each quarter during the 1st year warranty period.

## PART 2 - PRODUCTS

### 2.1 TRANE TRACER SC BUILDING AUTOMATION SYSTEM

- A. The controls contractor shall provide a complete building DDC control system to comply with the following specification. Basis of design is Trane tracer SC system. Provide a global control system that can communicate with all HVAC equipment. The system shall be viewable and editable from a computer using internet web browser communicating either directly or remotely with the bas main control panel. The control system shall be provided by the HVAC equipment manufacturer
- B. General System Requirements:
1. Direct digital control (DDC) technology shall be used to provide the functions necessary for control of all mechanical systems.
  2. The control system shall be designed such that in the event of a network communication failure, or the loss of any other controller, the control system shall continue to independently operate under control.
  3. Owner shall provide wan/LAN connection to the building automation system for remote access.
  4. Unit level controllers shall use BACnet MS/TP protocol. Controllers shall be BACnet BTL certified.
  5. The system must be provided, installed, wired, and programed by the equipment manufacturer's local factory office. Bids by wholesalers, contractors, franchised dealers, or any other firm whose principle business is not that of manufacturing and installing HVAC equipment and building automation systems is not acceptable.
  6. Provide one year parts and labor warranty of the bas.
  7. Provide 16 hours of owner's training at jobsite on the building automation system operation.
- C. The system shall have the following functions:
1. Time of day scheduling including optimal start/stop, holiday, and exception schedules.
  2. Timed override based on duration limit or fixed until released.
  3. Data logging and trending.
  4. User security level assignment.
  5. System and alarms reports.

6. Floor plans, system, equipment graphics with dynamic data display.
  7. Alarm e-mail routing.
  8. Global navigation icons to manage alarms, user credentials, help functions.
  9. Support a minimum of 5 concurrent users.
  10. BACnet unit level controllers shall be BTL certified.
- D. The system shall have the following programming standard applications:
1. Static pressure setpoint optimization as defined by ASHRAE 90.1-2010.
  2. Demand control ventilation optimization as defined by ASHRAE 62.1-2004.
  3. Wireless compatibility with ZigBee building automation certified wireless communications interface.
  4. Free downloadable mobile device apps.
- E. Installation requirements:
1. Install all exposed wiring or in mechanical room in conduit.
  2. Where class 2 wires are in concealed and accessible locations, including above lay-in ceiling space, approved plenum rated cables not in raceway may be used.
- F. Graphics:
1. The following graphics shall be provided thru the DDC control system.
    - a. Building floor plans.
    - b. Packaged units.
    - c. Electric duct heaters.
    - d. Exhaust fans.
    - e. Humidifier.

### 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. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.



- E. Proceed with installation only after unsatisfactory conditions have been corrected.

### 3.2 DDC SYSTEM INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT

#### A. Communication Interface to Equipment with Integral Controls:

1. DDC system shall have communication interface with equipment having integral controls and having a communication interface for remote monitoring or control.
2. Equipment to Be Connected:
  - a. Self-contained steam humidifiers specified in Section 238413.29 "Self-Contained Steam Humidifiers."
  - b. Packaged units specified in Section 237416.13 - Packaged, Large-Capacity, Rooftop Air-Conditioning Units.

### 3.3 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, wiring and raceways. Brace products to prevent lateral movement and sway or a break in attachment when subjected to a force.
- 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. Firestop Penetrations Made in Fire-Rated Assemblies: Comply with requirements in Section 078413 "Penetration Firestopping."
- G. Seal penetrations made in acoustically rated assemblies. Comply with requirements in Section 079200 "Joint Sealants."
- H. Welding Requirements:
  1. Restrict welding and burning to supports and bracing.
  2. No equipment shall be cut or welded without approval. Welding or cutting will not be approved if there is risk of damage to adjacent Work.
  3. Welding, where approved, shall be by inert-gas electric arc process and shall be performed by qualified welders according to applicable welding codes.
  4. If requested on-site, show satisfactory evidence of welder certificates indicating ability to perform welding work intended.
- I. Fastening Hardware:
  1. Stillson wrenches, pliers, and other tools that damage surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening fasteners.

2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
  3. Lubricate threads of bolts, nuts and screws with graphite and oil before assembly.
- J. 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.

### 3.4 WORKSTATION INSTALLATION

#### A. Desktop Workstations Installation:

1. Install workstation(s) at location(s) directed by Owner.
2. Install multiple-receptacle power strip with cord for use in connecting multiple workstation components to a single duplex electrical power receptacle.
3. Install software on workstation(s) and verify software functions properly.
4. Develop Project-specific graphics, trends, reports, logs and historical database.
5. Power [**each**] workstation through a [**dedicated**] UPS unit. Locate UPS adjacent to workstation.

#### B. Portable Workstations Installation:

1. Turn over portable workstations to Owner at Substantial Completion.
2. Install software on workstation(s) and verify software functions properly.

#### C. Color Graphics Application:

1. Use system schematics indicated as starting point to create graphics.
2. Develop Project-specific library of symbols for representing system equipment and products.
3. Incorporate digital images of Project-completed installation into graphics where beneficial to enhance effect.
4. Submit sketch of graphic layout with description of all text for each graphic for Owner's[ **and Architect's**] review before creating graphic using graphics software.
5. Seek Owner input in graphics development once using graphics software.
6. Final editing shall be done on-site with Owner's[ **and Architect's**] review and feedback.
7. Refine graphics as necessary for Owner acceptance.
8. On receiving Owner acceptance, print a hard copy for inclusion in operation and maintenance manual. Prepare a scanned copy PDF file of each graphic and include with softcopy of DDC system operation and maintenance manual.

#### D. Wall-Mounted Portable Operator's Workstation Cabinet Installation:

1. Install wall-mounted portable operator's workstation cabinet(s) at location(s) indicated on Drawings.
2. Install wall-mounted portable operator's workstation cabinet(s) at following location(s) and at locations directed by Owner:
  - a. Each mechanical room.
  - b. Chiller room.
  - c. Boiler room.

d. <Insert location>.

3. Connect each cabinet to [120-V, single-phase, 60Hz] <Insert power requirements> field power source, and install single gang electrical box with [NEMA WD 6, Type 20R duplex] <Insert receptacle type> receptacle and metal cover plate in cabinet. Comply with requirements in Section 262726 "Wiring Devices."
4. Connect each cabinet to Ethernet network and install an Ethernet network port for connection to portable operator workstation Ethernet cable. Comply with requirements in Section 271513 "Communications Copper Horizontal Cabling."

### 3.5 POT INSTALLATION

- A. Install [one] [two] <Insert quantity> portable operator terminal(s).
- B. Turn over POTs to Owner at Substantial Completion.
- C. Install software on each POT and verify that software functions properly.

### 3.6 SERVER INSTALLATION

- A. Install [one] [two] <Insert quantity> server(s) at location(s) directed by Owner.
- B. Install number of servers required to suit requirements indicated. Review Project requirements and indicate layout of proposed location in Shop Drawings.
- C. Install software indicated on server(s) and verify that software functions properly.
- D. Develop Project-specific graphics, trends, reports, logs, and historical database.
- E. Power servers through [dedicated] UPS unit. Locate UPS adjacent to server.

### 3.7 PRINTER INSTALLATION

- A. Provide the following printer(s) at location(s) directed by Owner:
  1. Black and White Laser: Quantity, [one] [one per desktop workstation] <Insert quantity>.
  2. Color Laser: Quantity, [one] [one per desktop workstation] <Insert quantity>.
  3. Color Inkjet: Quantity, [one] [one per desktop workstation] <Insert quantity>.
  4. Dot Matrix: Quantity, [one] [one per desktop workstation] <Insert quantity>.
- B. Install printer software on workstations and verify that software functions properly.

### 3.8 GATEWAY INSTALLATION

- A. Install gateways if required for DDC system communication interface requirements indicated.
  1. Install gateway(s) required to suit indicated requirements.
    - a. <Insert requirements>.
- B. Test gateway to verify that communication interface functions properly.

### 3.9 ROUTER INSTALLATION

- A. Install routers if required for DDC system communication interface requirements indicated.
  - 1. Install router(s) required to suit indicated requirements.
    - a. **<Insert requirements>**.
- B. Test router to verify that communication interface functions properly.

### 3.10 CONTROLLER INSTALLATION

- A. Install controllers in enclosures to comply with indicated requirements.
- B. Connect controllers to field power supply[ **and to UPS units where indicated**].
- 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.
  - 3. Top of controller shall be within [72 inches (1800 mm)] [84 inches (2100 mm)] **<Insert dimension>** of finished floor.
- 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.
  - 3. Top of controller shall be within [72 inches (1800 mm)] [84 inches (2100 mm)] **<Insert dimension>** of finished floor.
- 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.

### 3.11 INSTALLATION OF WIRELESS ROUTERS FOR OPERATOR INTERFACE

- A. Install wireless routers to achieve optimum performance and best possible coverage.
- B. Mount wireless routers in a protected location that is within 60 inches (1500 mm) of floor and easily accessible by operators.

- C. Connect wireless routers to field power supply and to UPS units if network controllers are powered through UPS units.
- D. Install wireless router with latest version of applicable software and configure wireless router with WPA2 security and password protection. Create access password with not less than 12 characters consisting of letters and numbers and at least one special character. Document password in operations and maintenance manuals for reference by operators.
- E. Test and adjust wireless routers for proper operation with portable workstation and other wireless devices intended for use by operators.

### 3.12 ENCLOSURES INSTALLATION

- A. Install the following items in enclosures, to comply with indicated requirements:
  - 1. Gateways.
  - 2. Routers.
  - 3. Controllers.
  - 4. Electrical power devices.
  - 5. UPS units.
  - 6. Relays.
  - 7. Accessories.
  - 8. Instruments.
  - 9. Actuators
  - 10. **<Insert devices>**.
- B. Attach wall-mounted enclosures to wall using the following types of steel struts:
  - 1. For NEMA 250, **[Type 1] <Insert type>** Enclosures: Use **[painted steel] [galvanized-steel] [corrosion-resistant-coated steel]** strut and hardware.
  - 2. For NEMA 250, **[Type 4] [Type 4X] <Insert type>** Enclosures and Enclosures Located Outdoors: Use stainless-steel strut and hardware.
  - 3. Install plastic caps on exposed cut edges of strut.
- C. Align **[top] [or] [bottom]** of adjacent enclosures[ **of like size**].
- D. Install floor-mounted enclosures located **[in mechanical equipment rooms]** on concrete housekeeping pads. Attach enclosure legs using **[galvanized-] [or] [stainless-]**steel anchors.
- E. Install continuous and fully accessible wireways to connect conduit, wire, and cable to multiple adjacent enclosures. Wireway used for application shall have protection equal to NEMA 250 rating of connected enclosures.

### 3.13 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.

- C. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers" for electrical power circuit breakers.
- D. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for electrical power conductors and cables.
- E. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for electrical power raceways and boxes.

### 3.14 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements in Section 260553 "Identification for Electrical Systems" for identification products and installation.
- B. Install **[self-adhesive labels]** **[laminated acrylic or melamine plastic signs]** with unique identification on face for each of the following:
  - 1. Operator workstation.
  - 2. Server.
  - 3. Printer.
  - 4. Gateway.
  - 5. Router.
  - 6. Protocol analyzer.
  - 7. DDC controller.
  - 8. Enclosure.
  - 9. Electrical power device.
  - 10. UPS unit.
  - 11. Accessory.
- C. Install unique instrument identification on face of each instrument connected to a DDC controller.
- D. Install unique identification on face of each control **[damper]** **[and]** **[valve]** actuator connected to a DDC controller.
- E. Where product is installed above accessible tile ceiling, also install matching identification on face of ceiling grid located directly below.
- F. Where product is installed above an inaccessible ceiling, also install identification on face of access door directly below.
- G. Warning Labels and Signs:
  - 1. Shall be permanently attached to equipment that can be automatically started by DDC control system.
  - 2. Shall be located in highly visible location near power service entry points.

### 3.15 NETWORK INSTALLATION

- A. Install optical fiber cable when connecting between the following network devices and when located in different buildings on campus, or when distance between devices exceeds **<Insert distance>**:
  - 1. Operator workstations.
  - 2. Operator workstations and network controllers.
  - 3. Network controllers.
  - 4. **<Insert network device>**.
- B. Install balanced twisted pair [**or optical fiber**] cable when connecting between the following network devices[ **located in same building**]:
  - 1. Operator workstations.
  - 2. Operator workstations and network controllers.
  - 3. Network controllers.
  - 4. **<Insert network device>**.
- C. Install balanced twisted pair or copper cable (as required by equipment) when connecting between the following:
  - 1. Gateways.
  - 2. Gateways and network controllers or programmable application controllers.
  - 3. Routers.
  - 4. Routers and network controllers or programmable application controllers.
  - 5. Network controllers and programmable application controllers.
  - 6. Programmable application controllers.
  - 7. Programmable application controllers and application-specific controllers.
  - 8. Application-specific controllers.
  - 9. **<Insert network device>**.
- D. Install cable in continuous raceway.
  - 1. Where indicated on Drawings, cable trays may be used for copper cable in lieu of conduit.

### 3.16 NETWORK NAMING AND NUMBERING

- A. Coordinate with Owner and provide unique naming and addressing for networks and devices.
- B. ASHRAE 135 Networks:
  - 1. MAC Address:
    - a. Every network device shall have an assigned and documented MAC address unique to its network.
    - b. Ethernet Networks: Document MAC address assigned at its creation.
    - c. ARCNET or MS/TP networks: Assign from 00 to 64.
  - 2. Network Numbering:

- a. Assign unique numbers to each new network.
  - b. Provide ability for changing network number through device switches or operator interface.
  - c. DDC system, with all possible connected LANs, can contain up to 65,534 unique networks.
3. Device Object Identifier Property Number:
  - a. Assign unique device object identifier property numbers or device instances for each device network.
  - b. Provide for future modification of device instance number by device switches or operator interface.
  - c. LAN shall support up to 4,194,302 unique devices.
4. Device Object Name Property Text:
  - a. Device object name property field shall support 32 minimum printable characters.
  - b. Assign unique device "Object Name" property names with plain-English descriptive names for each device.
    - 1) Example 1: Device object name for device controlling boiler plant at Building 1000 would be "HW System B1000."
    - 2) Example 2: Device object name for a VAV terminal unit controller could be "VAV unit 102".
5. Object Name Property Text for Other Than Device Objects:
  - a. Object name property field shall support 32 minimum printable characters.
  - b. Assign object name properties with plain-English names descriptive of application.
    - 1) Example 1: "Zone 1 Temperature."
    - 2) Example 2 "Fan Start and Stop."
6. Object Identifier Property Number for Other Than Device Objects:
  - a. Assign object identifier property numbers according to [Drawings] [or] [tables] indicated.
  - b. If not indicated, object identifier property numbers may be assigned at Installer's discretion but must be approved by Owner in advance, be documented and be unique for like object types within device.

### 3.17 PIPING AND TUBING INSTALLATION

#### A. Above-Grade Pneumatic and Air Signal Piping and Tubing Installation:

1. Material Application:
  - a. Install copper tubing, except as follows:
    - 1) Tubing Exposed to View: Polyethylene tubing installed in raceways may be used in lieu of copper tubing.



- 2) Concealed Tubing: Polyethylene tubing may be used in lieu of copper tubing when **[concealed behind accessible ceilings] [and] [concealed in walls and connecting wall-mounted instruments with recessed connections]**.
  - b. Install copper tubing for sizes up through **[NPS 1 (DN 25)]** <Insert size> and install galvanized-steel pipe for larger sizes, except as follows:
    - 1) Tubing Exposed to View: Polyethylene tubing installed in raceways may be used in lieu of copper tubing where exposed to view.
    - 2) Concealed Tubing: Polyethylene tubing may be used in lieu of copper tubing when **[concealed behind accessible ceilings] [and] [concealed in walls and connecting wall-mounted instruments with recessed connections]**.
  - c. Install copper tubing**[, unless other accessible materials are indicated,]** for pneumatic main and control signals to instruments including, but not limited to, the following:
    - 1) Pneumatic actuators.
    - 2) I/P transducers.
    - 3) Sensors.
    - 4) Switches.
    - 5) Transmitters.
    - 6) **<Insert instrument>**.
  - d. Install copper tubing**[, unless other accessible materials are indicated,]** for air signals to instruments including, but not limited to, the following:
    - 1) Sensors.
    - 2) Switches.
    - 3) Transmitters.
    - 4) **<Insert instrument>**.
  - e. Install drawn-temper copper tubing, except within **36 inches (900 mm)** of device terminations tubing shall be annealed-tempered copper tubing.
  - f. Install compression fittings to connect copper tubing to instruments, control devices, and accessories.
  - g. Install **[barbed] [or] [compression]** fittings to connect polyethylene tubing to instruments, control devices, and accessories.
2. Routing:
  - a. Do not expose tubing in finished spaces, such as spaces with ceilings; occupied spaces, offices, and conference rooms, unless expressly approved in writing by Architect. Tubing may be exposed in areas without ceilings.
  - b. Where tubing is installed in finished occupied spaces, install the tubing in surface metal raceway with appropriate fittings only where not feasible to conceal in wall, above ceiling or behind architectural enclosures or covers.
  - c. Install piping and tubing plumb and parallel to and at right angles with building construction.

- d. Install multiple runs of tubing or piping in equally spaced parallel lines.
  - e. Piping and tubing shall not interfere with access to valves, equipment, duct and equipment access doors, or obstruct personnel access and passageways of any kind.
  - f. Coordinate with other trades before installation to prevent proposed piping and tubing from interfering with pipe, duct, terminal equipment, light fixtures, conduit and cable tray space. If changes to Shop Drawings are necessary due to field coordination, document changes on record Drawings.
  - g. Install vibration loops in copper tubing when connecting to instrument and actuators that vibrate.
3. Support:
- a. According to MSS SP-69, Table 3, except support spacing shall not exceed **60 inches (1500 mm)**.
  - b. Support copper tubing with copper hangers, clips, and tube trays.
  - c. Do not use tape for support or dielectric isolation.
  - d. Install supports at each change in direction and at each branch take off.
  - e. Attached supports to building structure independent of work of other trades. Support from ducts, pipes, cable trays, and conduits is prohibited.
  - f. Attached support from building structure with threaded rods, structural shapes, or channel strut.
  - g. Install and brace supports to carry static load plus a safety margin, which will allow tubing to be serviced.
  - h. Brace supports to prevent lateral movement.
  - i. Paint steel support members that are not galvanized or zinc coated.
  - j. Support polyethylene tubing same as copper tubing.
4. Do not attach piping and tubing to equipment that may be removed frequently for maintenance or that may impart vibration and expansion from temperature change.
5. Protect exposed tubing in mechanical equipment rooms from mechanical damage within **[76 inches (1800 mm)] [84 inches (2100 mm)] [96 inches (2400 mm)]** **<Insert dimension>** above floor. Use aluminum channel reversed and secured over tubing to protect tubing from damage.
6. Joining and Makeup:
- a. Where joining and mating dissimilar metals where galvanic action could occur, install dielectric isolation.
  - b. Install a dirt leg with an isolation valve and threaded plug at each main air, connection to a panel, pneumatic pilot positioner and PRV station.
  - c. Make threaded joints for connecting to instrument equipment with connectors with a compression tubing connector on one end and threaded connection on other end.
  - d. Make tubing bends with a tube-bending tool. Hard bends, wrinkled or flattened bends are unacceptable.
  - e. Install tube fittings according to manufacturer's written instructions.
  - f. Do not make tubing connections to a fitting before completing makeup of the connection.
  - g. Align tubing with the fitting. Avoid springing tube into position, as this may result in excessive stress on both tubing and fitting with possible resulting leaks.
  - h. Do not install fittings close to a bend. A length of straight tubing, not deformed by bending, is required for a proper connection.

- i. Check tubing for correct diameter and wall thickness.
    - j. Tube ends shall be cut square and deburred. Exercise care during cutting to keep tubing round.
    - k. Thread pipe on a threading machine. Ream inner edges of pipe ends, file and grind to remove burrs.
    - l. Wrap pipe threads of fittings on pneumatic lines with a single wrap of PTFE tape.
    - m. Protect piping and tubing from entrance of foreign matter.
  7. Conduit in which nonmetallic tubing is installed shall not exceed 50 percent fill. Support conduit according to NFPA 70 unless otherwise indicated.
- B. Below-Grade Pneumatic and Air Signal Piping and Tubing Installation:
1. Install tubing below grade in a continuous **4-inch (100-mm)**, Schedule 80, PVC conduit.
  2. Install at a depth of at least **24 inches (600 mm)** below finished grade.
  3. Install tubing in raceways dedicated to tubing. Do not combine electrical conductors and tubing in raceways.
- C. Identify piping and tubing as follows:
1. Every **50 feet (15 m)** of straight run.
  2. At least once for each branch within **36 inches (900 mm)** of main tee.
  3. At each change in direction.
  4. Within **36 inches (900 mm)** of each ceiling, floor, roof and wall penetration.
  5. Where exposed to and where concealed from view, including above ceiling plenums, shafts, and chases.
  6. At each valve.
  7. Mark each instrument tube connection with a number-coded identification. Each unique tube shall have same unique number at instrument connection and termination at opposite end of tube.
- D. Isolation Valves Installation:
1. Install valves full size of piping and tubing.
  2. Install at the following locations:
    - a. At each branch.
    - b. Before and after each PRV.
    - c. Before and after each air dryer.
    - d. At each control device.
  3. Valves shall be located to be readily accessible from floor.
- E. Process Tubing Installation:
1. Install process tubing for signal to instruments in liquid and steam systems. Instruments include, but are not limited to, the following:
    - a. Meters.
    - b. Sensors.
    - c. Switches.

## d. Transmitters.

2. Support tubing according to MSS SP-69, Table 3, but at intervals no less than **60 inches (1500 mm)**.
3. Install **NPS 1/2 (DN 15)** process tubing for industrial-grade sensors, transmitters, and switches. Install stainless-steel bushings where required.
4. Make tubing bends with a bending tool. Flattened or wrinkled bends are unacceptable.
5. Support tubing independent of other trades.
6. Route tubing parallel to and at right angles to building construction.
7. Install tubing concealed in areas with ceilings.
8. Install a dirt leg with an isolation valve and threaded plug in drain valve at each connection to a transmitter and switch.
9. Insulate process piping connected to hot water and steam systems for personnel protection if the surface temperature exceeds **120 deg F (49 deg C)**. Only insulate piping within maintenance personnel reach from floor, platform, or catwalk.
10. Wrap pipe threads of fitting in process tubing with service temperatures below **350 deg F (177 deg C)** with a single wrap of PTFE tape.
11. Coat pipe threads of fittings on process tubing in services with temperatures exceeding **350 deg F (177 deg C)** with pipe compound before being made up to reduce the possibility of galling.
12. Do not make tubing connections to a fitting before completing makeup of the connection.
13. Check tubing for correct diameter and wall thickness. Cut the tube ends square and deburred. Exercise care during cutting to keep tubing round.
14. Do not install fittings close to a bend. A length of straight tubing, not deformed by bending, is required for a proper connection.
15. Align tubing with fitting when installed. Avoid springing tube into position.
16. Install tubing with extreme care exercised to keep foreign matter out of system. Open tubing ends shall be kept plugged to keep out dust, dirt and moisture.
17. Do not attach tubing to equipment that may be removed frequently for maintenance or may impart vibration and expansion from temperature change.
18. Protect exposed tubing in mechanical equipment rooms from inadvertent mechanical damage within [**76 inches (1800 mm)**] [**84 inches (2100 mm)**] [**96 inches (2400 mm)**] **<Insert dimension>** above floor. Use aluminum channel reversed and secured over tubing to protect tubing from damage.

## F. Isolation Valves Installation:

1. Install valves full size of piping and tubing.
2. Install isolation valves at the following locations:
  - a. Process connection.
  - b. Inlet to each instrument including, sensors, transmitters, switches, gages, and other control devices.
3. Locate valves to be readily accessible from floor.

## 3.18 CONTROL WIRE, CABLE AND RACEWAYS INSTALLATION

## A. Comply with NECA 1.

## B. Wire and Cable Installation:

1. Comply with installation requirements in Section 260523 "Control-Voltage Electrical Power Cables."
2. Comply with installation requirements in Section 271313 "Communications Copper Backbone Cabling."
3. Comply with installation requirements in Section 271513 "Communications Copper Horizontal Cabling."
4. Install cables with protective sheathing that is waterproof and capable of withstanding continuous temperatures of 90 deg C with no measurable effect on physical and electrical properties of cable.
  - a. Provide shielding to prevent interference and distortion from adjacent cables and equipment.
5. Terminate wiring in a junction box.
  - a. Clamp cable over jacket in junction box.
  - b. Individual conductors in the stripped section of the cable shall be slack between the clamping point and terminal block.
6. Terminate field wiring and cable not directly connected to instruments and control devices having integral wiring terminals using terminal blocks.
7. Install signal transmission components according to IEEE C2, REA Form 511a, NFPA 70, and as indicated.
8. Use shielded cable to transmitters.
9. Use shielded cable to temperature sensors.
10. Perform continuity and meager testing on wire and cable after installation.

C. Conduit Installation:

1. Comply with Section "260533 "Raceways and Boxes for Electrical Systems" for control-voltage conductors.
2. Comply with Section 270528 "Pathways for Communications Systems" for balanced twisted pair cabling and optical fiber installation.

3.19 OPTICAL FIBER CABLE SYSTEM INSTALLATION

- A. Comply with installation requirements in Section 271323 "Communications Optical Fiber Backbone Cabling."
- B. Comply with installation requirements in Section 271523 "Communications Optical Fiber Horizontal Cabling."

3.20 FIELD QUALITY CONTROL

- A. Testing Agency: **[Owner will engage] [Engage]** a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.

C. Perform the following tests and inspections[ **with the assistance of a factory-authorized service representative**]:

1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Testing of Pneumatic and Air-Signal Tubing:
  - a. Test for leaks and obstructions.
  - b. Disconnect each pipe and tubing line before a test is performed, and blowout dust, dirt, trash, condensate and other foreign materials with compressed air. Use commercially pure compressed air or nitrogen as distributed in gas cylinders. Air from an oil-free compressor with an air dryer is an acceptable alternative for the test.
  - c. After foreign matter is expelled and line is free from obstructions, plug far end of tubing run.
  - d. Connect a pressure source to near end of run with a needle valve between air supply and tubing run.
  - e. Connect a pressure gage accurate to within 0.5 percent of test between the shutoff needle valve and tubing run under test.
  - f. For system pressures above **30 psig (207 kPa)**, apply a pressure of 1.5 times operating pressure. Record pressure in tubing run every 10 minutes for one hour. Allowable drop in pressure in one-hour period shall not exceed **1 psig (6.9 kPa)**.
  - g. For system pressures **30 psig (207 kPa)** and below, apply a pressure of 2.0 times operating pressure to piping and tubing run. Record pressure in tubing run every 5 minutes for one hour. Allowable drop in pressure in one-hour period shall not exceed **0.5 psig (3.5 kPa)**.

D. Testing:

1. Perform preinstallation, in-progress, and final tests, supplemented by additional tests, as necessary.
2. Preinstallation Cable Verification: Verify integrity and serviceability for new cable lengths before installation. This assurance may be provided by using vendor verification documents, testing, or other methods. As a minimum, furnish evidence of verification for cable attenuation and bandwidth parameters.
3. In-Progress Testing: Perform standard tests for correct pair identification and termination during installation to ensure proper installation and cable placement. Perform tests in addition to those specified if there is any reason to question condition of material furnished and installed. Testing accomplished is to be documented by agency conducting tests. Submit test results for Project record.
4. Final Testing: Perform final test of installed system to demonstrate acceptability as installed. Testing shall be performed according to a test plan supplied by DDC system manufacturer. Defective Work or material shall be corrected and retested. As a minimum, final testing for cable system, including spare cable, shall verify conformance of attenuation, length, and bandwidth parameters with performance indicated.
5. Test Equipment: Use an optical fiber time domain reflectometer for testing of length and optical connectivity.
6. Test Results: Record test results and submit copy of test results for Project record.

## 3.21 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.
- E. For pneumatic products, verify that air supply for each product is properly installed.
- F. Control Damper Checkout:
  - 1. For pneumatic dampers, verify that pressure gages are provided in each air line to damper actuator and positioner.
  - 2. Verify that control dampers are installed correctly for flow direction.
  - 3. Verify that proper blade alignment, either parallel or opposed, has been provided.
  - 4. Verify that damper frame attachment is properly secured and sealed.
  - 5. Verify that damper actuator and linkage attachment is secure.
  - 6. Verify that actuator wiring is complete, enclosed and connected to correct power source.
  - 7. Verify that damper blade travel is unobstructed.
- G. Control Valve Checkout:
  - 1. For pneumatic valves, verify that pressure gages are provided in each air line to valve actuator and positioner.
  - 2. Verify that control valves are installed correctly for flow direction.
  - 3. Verify that valve body attachment is properly secured and sealed.
  - 4. Verify that valve actuator and linkage attachment is secure.
  - 5. Verify that actuator wiring is complete, enclosed and connected to correct power source.
  - 6. Verify that valve ball, disc or plug travel is unobstructed.
  - 7. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.
- H. Instrument Checkout:
  - 1. Verify that instrument is correctly installed for location, orientation, direction and operating clearances.
  - 2. Verify that attachment is properly secured and sealed.
  - 3. Verify that conduit connections are properly secured and sealed.
  - 4. Verify that wiring is properly labeled with unique identification, correct type and size and is securely attached to proper terminals.
  - 5. Inspect instrument tag against approved submittal.
  - 6. For instruments with tubing connections, verify that tubing attachment is secure and isolation valves have been provided.
  - 7. For flow instruments, verify that recommended upstream and downstream distances have been maintained.

8. For temperature instruments:
  - a. Verify sensing element type and proper material.
  - b. Verify length and insertion.

### 3.22 DDC SYSTEM I/O ADJUSTMENT, CALIBRATION AND TESTING:

- A. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
- B. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
- C. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
- D. Equipment and procedures used for calibration shall comply with instrument manufacturer's written instructions.
- E. Provide diagnostic and test equipment for calibration and adjustment.
- F. 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.
- G. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
- H. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
- I. 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.
- J. 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.
- K. Digital Signals:
  1. Check digital signals using a jumper wire.
  2. Check digital signals using an ohmmeter to test for contact making or breaking.
- L. 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.

M. 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.

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

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

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

Q. 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.

### 3.23 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.

### 3.24 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.

### 3.25 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 [10] [20] <Insert number> 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. After 24 Hours following Initial Validation Test:

- a. Re-check I/O points that required corrections during initial test.
    - b. Identify I/O points that still require additional correction and make corrections necessary to achieve desired results.
  5. After 24 Hours of Second Validation Test:
    - a. Re-check I/O points that required corrections during second test.
    - b. Continue validation testing until I/O point is normal on two consecutive tests.
  6. Completely check out, calibrate, and test all connected hardware and software to ensure that DDC system performs according to requirements indicated.
  7. 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.
- G. DDC System Response Time Test:
1. Simulate HLC.
    - a. Heavy load shall be an occurrence of [50] <Insert number> percent of total connected binary COV, one-half of which represent an "alarm" condition, and [50] <Insert number> percent of total connected analog COV, one-half of which represent an "alarm" condition, that are initiated simultaneously on a one-time basis.
  2. Initiate 10 successive occurrences of HLC and measure response time to typical alarms and status changes.
  3. Measure with a timer having at least 0.1-second resolution and 0.01 percent accuracy.
  4. Purpose of test is to demonstrate DDC system, as follows:
    - a. Reaction to COV and alarm conditions during HLC.
    - b. Ability to update DDC system database during HLC.
  5. Passing test is contingent on the following:
    - a. Alarm reporting at printer beginning no more than [two] <Insert number> seconds after the initiation (time zero) of HLC.
    - b. All alarms, both binary and analog, are reported and printed; none are lost.
    - c. Compliance with response times specified.
  6. Prepare and submit a report documenting HLC tested and results of test including time stamp and print out of all alarms.
- H. DDC System Network Bandwidth Test:
1. Test network bandwidth usage on all DDC system networks to demonstrate bandwidth usage under DDC system normal operating conditions and under simulated HLC.
  2. To pass, none of DDC system networks shall use more than 70 percent of available bandwidth under normal and HLC operation.

## 3.26 DDC SYSTEM WIRELESS NETWORK VERIFICATION

- A. DDC system Installer shall design wireless DDC system networks to comply with performance requirements indicated.
- B. Installer shall verify wireless network performance through field testing and shall document results in a field test report.
- C. Testing and verification of all wireless devices shall include, but not be limited to, the following:
  - 1. Speed.
  - 2. Online status.
  - 3. Signal strength.

## 3.27 FINAL REVIEW

- A. Submit written request to Architect **[and] [Construction Manager]** when DDC system is ready for final review. Written request shall state the following:
  - 1. DDC system has been thoroughly inspected for compliance with contract documents and found to be in full compliance.
  - 2. DDC system has been calibrated, adjusted and tested and found to comply with requirements of operational stability, accuracy, speed and other performance requirements indicated.
  - 3. DDC system monitoring and control of HVAC systems results in operation according to sequences of operation indicated.
  - 4. DDC system is complete and ready for final review.
- B. Review by **[Architect] [and] [Construction Manager]** shall be made after receipt of written request. A field report shall be issued to document observations and deficiencies.
- C. Take prompt action to remedy deficiencies indicated in field report and submit a second written request when all deficiencies have been corrected. Repeat process until no deficiencies are reported.
- D. Should more than two reviews be required, DDC system manufacturer and Installer shall compensate entity performing review for total costs, labor and expenses, associated with third and subsequent reviews. Estimated cost of each review shall be submitted and approved by DDC system manufacturer and Installer before making the review.
- E. Prepare and submit closeout submittals **[and begin procedures indicated in "Extended Operation Test" Article]** when no deficiencies are reported.
- F. A part of DDC system final review shall include a demonstration to parties participating in final review.
  - 1. Provide staff familiar with DDC system installed to demonstrate operation of DDC system during final review.
  - 2. Provide testing equipment to demonstrate accuracy and other performance requirements of DDC system that is requested by reviewers during final review.

3. Demonstration shall include, but not be limited to, the following:
- a. Accuracy and calibration of [10] [20] <Insert number> I/O points randomly selected by reviewers. If review finds that some I/O points are not properly calibrated and not satisfying performance requirements indicated, additional I/O points may be selected by reviewers until total I/O points being reviewed that satisfy requirements equals quantity indicated.
  - b. HVAC equipment and system hardwired and software safeties and life-safety functions are operating according to sequence of operation. Up to [10] [20] <Insert number> I/O points shall be randomly selected by reviewers. Additional I/O points may be selected by reviewers to discover problems with operation.
  - c. Correct sequence of operation after electrical power interruption and resumption after electrical power is restored for randomly selected HVAC systems.
  - d. Operation of randomly selected dampers and valves in normal-on, normal-off and failed positions.
  - e. Reporting of alarm conditions for randomly selected alarms, including different classes of alarms, to ensure that alarms are properly received by operators and operator workstations.
  - f. Trends, summaries, logs and reports set-up for Project.
  - g. For up to [three] <Insert number> HVAC systems randomly selected by reviewers, use graph trends to show that sequence of operation is executed in correct manner and that HVAC systems operate properly through complete sequence of operation including different modes of operations indicated. Show that control loops are stable and operating at set points and respond to changes in set point of 20 percent or more.
  - h. Software's ability to communicate with controllers, operator workstations, uploading and downloading of control programs.
  - i. Software's ability to edit control programs off-line.
  - j. Data entry to show Project-specific customizing capability including parameter changes.
  - k. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.
  - l. Execution of digital and analog commands in graphic mode.
  - m. Spreadsheet and curve plot software and its integration with database.
  - n. Online user guide and help functions.
  - o. Multitasking by showing different operations occurring simultaneously on four quadrants of split screen.
  - p. System speed of response compared to requirements indicated.
  - q. For Each [Network] [and] [Programmable Application] Controller:
    - 1) Memory: Programmed data, parameters, trend and alarm history collected during normal operation is not lost during power failure.
    - 2) Operator Interface: Ability to connect directly to each type of digital controller with a portable workstation and mobile device. Show that maintenance personnel interface tools perform as indicated in manufacturer's technical literature.
    - 3) Standalone Ability: Demonstrate that controllers provide stable and reliable standalone operation using default values or other method for values normally read over network.
    - 4) Electric Power: Ability to disconnect any controller safely from its power source.

- 5) Wiring Labels: Match control drawings.
  - 6) Network Communication: Ability to locate a controller's location on network and communication architecture matches Shop Drawings.
  - 7) Nameplates and Tags: Accurate and permanently attached to control panel doors, instrument, actuators and devices.
- r. For Each Operator Workstation:
- 1) I/O points lists agree with naming conventions.
  - 2) Graphics are complete.
  - 3) UPS unit, if applicable, operates.
- s. Communications and Interoperability: Demonstrate proper interoperability of data sharing, alarm and event management, trending, scheduling, and device and network management.[ **Use ASHRAE 135 protocol analyzer to help identify devices, view network traffic, and verify interoperability.**] Requirements must be met even if only one manufacturer's equipment is installed.
- 1) Data Presentation: On each operator workstation, demonstrate graphic display capabilities.
  - 2) Reading of Any Property: Demonstrate ability to read and display any used readable object property of any device on network.
  - 3) Set Point and Parameter Modifications: Show ability to modify set points and tuning parameters indicated.[ **Modifications are made with messages and write services initiated by an operator using workstation graphics, or by completing a field in a menu with instructional text.**]
  - 4) Peer-to-Peer Data Exchange: Network devices are installed and configured to perform without need for operator intervention to implement Project sequence of operation and to share global data.
  - 5) Alarm and Event Management: Alarms and events are installed and prioritized according to Owner. Demonstrate that time delays and other logic are set up to avoid nuisance tripping. Show that operators with sufficient privileges are permitted.
  - 6) Schedule Lists: Schedules are configured for start and stop, mode change, occupant overrides, and night setback as defined in sequence of operations.
  - 7) Schedule Display and Modification: Ability to display any schedule with start and stop times for calendar year. Show that all calendar entries and schedules are modifiable from any connected operator workstation by an operator with sufficient privilege.
  - 8) Archival Storage of Data: Data archiving is handled by operator workstation and server and local trend archiving and display is accomplished.
  - 9) Modification of Trend Log Object Parameters: Operator with sufficient privilege can change logged data points, sampling rate, and trend duration.
  - 10) Device and Network Management:
    - a) Display of network device status.
    - b) Display of BACnet Object Information.
    - c) Silencing devices transmitting erroneous data.
    - d) Time synchronization.
    - e) Remote device re-initialization.

- f) Backup and restore network device programming and master database(s).
- g) Configuration management of routers.

t. <Insert additional requirements>.

### 3.28 EXTENDED OPERATION TEST

- A. Extended operation test is intended to simulate normal operation of DDC system by Owner.
- B. Operate DDC system for an operating period of [14] [21] [28] <Insert number> consecutive calendar days following Substantial Completion. Coordinate exact start date of testing with Owner.
- C. Provide an operator familiar with DDC system installed to man an operator workstation [**while on-site**] during eight hours of each normal business day occurring during operating period.
- D. During operating period, DDC system shall demonstrate correct operation and accuracy of monitored and controlled points as well as operation capabilities of sequences, logs, trends, reports, specialized control algorithms, diagnostics, and other software indicated.
  - 1. Correct defects of hardware and software when it occurs.
- E. Definition of Failures and Downtime during Operating Period:
  - 1. Failed I/O point constituting downtime is an I/O point failing to perform its intended function consistently and a point physically failed due to hardware and software.
  - 2. Downtime is when any I/O point in DDC system is unable to fulfill its' required function.
  - 3. Downtime shall be calculated as elapsed time between a detected point failure as confirmed by an operator and time point is restored to service.
  - 4. Maximum time interval allowed between DDC system detection of failure occurrence and operator confirmation shall be 0.5 hours.
  - 5. Downtime shall be logged in hours to nearest 0.1 hour.
  - 6. Power outages shall not count as downtime, but shall suspend test hours unless systems are provided with UPS and served through a backup power source.
  - 7. Hardware or software failures caused by power outages shall count as downtime.
- F. During operating period, log downtime and operational problems are encountered.
  - 1. Identify source of problem.
  - 2. Provide written description of corrective action taken.
  - 3. Record duration of downtime.
  - 4. Maintain log showing the following:
    - a. Time of occurrence.
    - b. Description of each occurrence and pertinent written comments for reviewer to understand scope and extent of occurrence.
    - c. Downtime for each failed I/O point.
    - d. Running total of downtime and total time of I/O point after each problem has been restored.



5. Log shall be available to Owner for review at any time.
  - G. For DDC system to pass extended operation test, total downtime shall not exceed [1] [2] <Insert number> percent of total point-hours during operating period.
    1. Failure to comply with minimum requirements of passing at end of operating period indicated shall require that operating period be extended one consecutive day at a time until DDC system passes requirement.
  - H. Evaluation of DDC system passing test shall be based on the following calculation:
    1. Downtime shall be counted on a point-hour basis where total number of DDC system point-hours is equal to total number of I/O points in DDC system multiplied by total number of hours during operating period.
    2. One point-hour of downtime is one I/O point down for one hour. Three points down for five hours is a total of 15 point-hours of downtime. Four points down for one-half hour is 2 point-hours of downtime.
    3. Example Calculation: Maximum allowable downtime for 30-day test when DDC system has 1000 total I/O points (combined analog and binary) and has passing score of 1 percent downtime is computed by 30 days x 24 h/day x 1000 points x 1 percent equals 7200 point-hours of maximum allowable downtime.
  - I. Prepare test and inspection reports.
- 3.29 ADJUSTING
- A. Occupancy Adjustments: When requested within [12] <Insert number> months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to [two] <Insert number> visits to Project during other-than-normal occupancy hours for this purpose.
- 3.30 MAINTENANCE SERVICE
- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include [three] [six] [nine] [12] <Insert number> months' full maintenance by DDC system manufacturer's authorized service representative. Include [monthly] [quarterly] [semiannual] [annual] preventive maintenance, repair or replacement of worn or defective components, cleaning, calibration and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.
- 3.31 SOFTWARE SERVICE AGREEMENT
- A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for [one] [two] <Insert number> year(s).
  - B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within [one] [two] <Insert number> year(s) from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.

1. Upgrade Notice: At least [30] <Insert number> days to allow Owner to schedule and access system and to upgrade computer equipment if necessary.

### 3.32 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 [five] [10] [15] <Insert number> days of training total.
    - b. Stagger training over multiple training classes to accommodate Owner's requirements. All training shall occur before end of warranty period.
    - c. Total days of training shall be broken into not more than [two] [three] [four] <Insert number> separate training classes.
    - d. Each training class shall be not less than [one] [two] [three] <Insert number> consecutive day(s).
- C. Training Schedule:
  1. Schedule training with Owner [20] <Insert number> business days before expected Substantial Completion.
  2. Schedule training to provide Owner with at least [10] [15] [20] <Insert number> business days of notice in advance of training.
  3. Training shall occur within normal business hours at a mutually agreed on time. Unless otherwise agreed to, training shall occur Monday through Friday, except on U.S. Federal holidays, with two morning sessions and two afternoon sessions. Each morning session and afternoon session shall be split in half with [15] [30] <Insert number>-minute break between sessions. Morning and afternoon sessions shall be separated by [30] [60] <Insert number>-minute lunch period. Training, including breaks and excluding lunch period, shall not exceed [eight] <Insert number> hours per day.
  4. Provide staggered training schedule as requested by Owner.
- D. Training Attendee List and Sign-in Sheet:
  1. Request from Owner in advance of training a proposed attendee list with name, phone number and e-mail address.
  2. Provide a preprinted sign-in sheet for each training session with proposed attendees listed and no fewer than six blank spaces to add additional attendees.
  3. Preprinted sign-in sheet shall include training session number, date and time, instructor name, phone number and e-mail address, and brief description of content to be covered during session. List attendees with columns for name, phone number, e-mail address and a column for attendee signature or initials.

4. Circulate sign-in sheet at beginning of each session and solicit attendees to sign or initial in applicable location.
  5. At end of each training day, send Owner an e-mail with an attachment of scanned copy (PDF) of circulated sign-in sheet for each session.
- E. Training Attendee Headcount:
1. Plan in advance of training for **[two]** **[three]** **[five]** **<Insert number>** attendees.
  2. Make allowance for Owner to add up to **[one]** **[two]** **<Insert number>** attendee(s) at time of training.
  3. Headcount may vary depending on training content covered in session. Attendee access may be restricted to some training content for purposes of maintaining system security.
- F. Training Attendee Prior Knowledge: For guidance in planning required training and instruction, assume attendees have the following:
1. **[High school]** **[High school and technical school]** **[High school and four-year college]** **<Insert level>** education and degree.
  2. **[Basic]** **[Intermediate]** **[Advanced]** user knowledge of computers and office applications.
  3. **[Basic]** **[Intermediate]** **[Advanced]** knowledge of HVAC systems.
  4. **[Basic]** **[Intermediate]** **[Advanced]** knowledge of DDC systems.
  5. **[Basic]** **[Intermediate]** **[Advanced]** knowledge of DDC system and products installed.
- G. Attendee Training Manuals:
1. Provide each attendee with a color hard copy of all training materials and visual presentations.
  2. Hard-copy materials shall be organized in a three-ring binder with table of contents and individual divider tabs marked for each logical grouping of subject matter. Organize material to provide space for attendees to take handwritten notes within training manuals.
  3. In addition to hard-copy materials included in training manual, provide each binder with a sleeve or pocket that includes a DVD or flash drive with PDF copy of all hard-copy materials.
- H. Instructor Requirements:
1. One or multiple qualified instructors, as required, to provide training.
  2. Instructors shall have not less than **[five]** **<Insert number>** years of providing instructional training on not less than **[five]** **<Insert number>** past projects with similar DDC system scope and complexity to DDC system installed.
- I. Organization of Training Sessions:
1. Organize training sessions into logical groupings of technical content and to reflect different levels of operators having access to system. Plan training sessions to accommodate the following three levels of operators:
    - a. Daily operators.
    - b. Advanced operators.
    - c. System managers and administrators.

2. Plan and organize training sessions to group training content to protect DDC system security. Some attendees may be restricted to some training sessions that cover restricted content for purposes of maintaining DDC system security.

J. Training Outline:

1. Submit training outline for Owner review at least [10] <Insert number> business day before scheduling training.
2. Outline shall include a detailed agenda for each training day that is broken down into each of four training sessions that day, training objectives for each training session and synopses for each lesson planned.

K. On-Site Training:

1. Owner will provide conditioned classroom or workspace with ample desks or tables, chairs, power and data connectivity for instructor and each attendee.
2. Instructor shall provide training materials, projector and other audiovisual equipment used in training.
3. Provide as much of training located on-site as deemed feasible and practical by Owner.
4. On-site training shall include regular walk-through tours, as required, to observe each unique product type installed with hands-on review of operation, calibration and service requirements.
5. Operator workstation provided with DDC system shall be used in training. If operator workstation is not indicated, provide a temporary workstation to convey training content.

L. Off-Site Training:

1. Provide conditioned training rooms and workspace with ample tables desks or tables, chairs, power and data connectivity for each attendee.
2. Provide capability to remotely access to Project DDC system for use in training.
3. Provide a workstation for use by each attendee.

M. Training Content for Daily Operators:

1. Basic operation of system.
2. Understanding DDC system architecture and configuration.
3. Understanding each unique product type installed including performance and service requirements for each.
4. Understanding operation of each system and equipment controlled by DDC system including sequences of operation, each unique control algorithm and each unique optimization routine.
5. Operating operator workstations, printers and other peripherals.
6. Logging on and off system.
7. Accessing graphics, reports and alarms.
8. Adjusting and changing set points and time schedules.
9. Recognizing DDC system malfunctions.
10. Understanding content of operation and maintenance manuals including control drawings.
11. Understanding physical location and placement of DDC controllers and I/O hardware.
12. Accessing data from DDC controllers.
13. Operating portable operator workstations.

14. Review of DDC testing results to establish basic understanding of DDC system operating performance and HVAC system limitations as of Substantial Completion.
15. Running each specified report and log.
16. Displaying and demonstrating each data entry to show Project-specific customizing capability. Demonstrating parameter changes.
17. Stepping through graphics penetration tree, displaying all graphics, demonstrating dynamic updating, and direct access to graphics.
18. Executing digital and analog commands in graphic mode.
19. Demonstrating control loop precision and stability via trend logs of I/O for not less than 10 percent of I/O installed.
20. Demonstrating DDC system performance through trend logs and command tracing.
21. Demonstrating scan, update, and alarm responsiveness.
22. Demonstrating spreadsheet and curve plot software, and its integration with database.
23. Demonstrating on-line user guide, and help function and mail facility.
24. Demonstrating multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
25. Demonstrating the following for HVAC systems and equipment controlled by DDC system:
  - a. Operation of HVAC equipment in normal-off, -on and failed conditions while observing individual equipment, dampers and valves for correct position under each condition.
  - b. For HVAC equipment with factory-installed software, show that integration into DDC system is able to communicate with DDC controllers or gateways, as applicable.
  - c. Using graphed trends, show that sequence of operation is executed in correct manner, and HVAC systems operate properly through complete sequence of operation including seasonal change, occupied and unoccupied modes, warm-up and cool-down cycles and other modes of operation indicated.
  - d. Hardware interlocks and safeties function properly and DDC system performs correct sequence of operation after electrical power interruption and resumption after power is restored.
  - e. Reporting of alarm conditions for each alarm, and confirm that alarms are received at assigned locations, including operator workstations.
  - f. Each control loop responds to set point adjustment and stabilizes within time period indicated.
  - g. Sharing of previously graphed trends of all control loops to demonstrate that each control loop is stable and set points are being maintained.

26. **<Insert requirement>.**

N. Training Content for Advanced Operators:

1. Making and changing workstation graphics.
2. Creating, deleting and modifying alarms including annunciation and routing.
3. Creating, deleting and modifying point trend logs including graphing and printing on an ad-hoc basis and operator-defined time intervals.
4. Creating, deleting and modifying reports.
5. Creating, deleting and modifying points.
6. Creating, deleting and modifying programming including ability to edit control programs off-line.

7. Creating, deleting and modifying system graphics and other types of displays.
  8. Adding DDC controllers and other network communication devices such as gateways and routers.
  9. Adding operator workstations.
  10. Performing DDC system checkout and diagnostic procedures.
  11. Performing DDC controllers operation and maintenance procedures.
  12. Performing operator workstation operation and maintenance procedures.
  13. Configuring DDC system hardware including controllers, workstations, communication devices and I/O points.
  14. Maintaining, calibrating, troubleshooting, diagnosing and repairing hardware.
  15. Adjusting, calibrating and replacing DDC system components.
  16. **<Insert requirement>**.
- O. Training Content for System Managers and Administrators:
1. DDC system software maintenance and backups.
  2. Uploading, downloading and off-line archiving of all DDC system software and databases.
  3. Interface with Project-specific, third-party operator software.
  4. Understanding password and security procedures.
  5. Adding new operators and making modifications to existing operators.
  6. Operator password assignments and modification.
  7. Operator authority assignment and modification.
  8. Workstation data segregation and modification.
  9. **<Insert requirement>**.
- P. Video of Training Sessions:
1. Provide a digital video and audio recording of each training session. Create a separate recording file for each session.
  2. Stamp each recording file with training session number, session name and date.
  3. Provide Owner with [two] **<Insert number>** copies of digital files on DVDs or flash drives for later reference and for use in future training.
  4. Owner retains right to make additional copies for intended training purposes without having to pay royalties.

END OF SECTION 230923