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.

B. Related Requirements:

1. Section 230993.11 "Sequence of Operations for HVAC DDC" for control sequences in DDC systems.
2. Communications Cabling:
   b. Section 271513 "Communications Copper Horizontal Cabling" for balanced twisted pair communications cable.

3. Raceways:
   a. Section 260533 "Raceways and Boxes for Electrical Systems" for raceways for low-voltage control cable.
   b. Section 270528 "Pathways for Communications Systems" for raceways for balanced twisted pair cabling and optical fiber cable.

4. Section 260553 "Identification for Electrical Systems" for identification requirements for electrical components.

1.3 DEFINITIONS

A. Algorithm: A logical procedure for solving a recurrent mathematical problem. A prescribed set of well-defined rules or processes for solving a problem in a finite number of steps.

B. Analog: A continuously varying signal value, such as current, flow, pressure, or temperature.

C. BACnet Specific Definitions:

2. BACnet Interoperability Building Blocks (BIBBs): BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBs are combined to build the BACnet functional requirements for a device.

3. BACnet/IP: Defines and allows using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP subnetworks that share the same BACnet network number.


5. PICS (Protocol Implementation Conformance Statement): Written document that identifies the particular options specified by BACnet that are implemented in a device.

D. Binary: Two-state signal where a high signal level represents "ON" or "OPEN" condition and a low signal level represents "OFF" or "CLOSED" condition. "Digital" is sometimes used interchangeably with "Binary" to indicate a two-state signal.

E. Controller: Generic term for any standalone, microprocessor-based, digital controller residing on a network, used for local or global control. Three types of controllers are indicated: Network Controller, Programmable Application Controller, and Application-Specific Controller.

F. Control System Integrator: An entity that assists in expansion of existing enterprise system and support of additional operator interfaces to I/O being added to existing enterprise system.

G. COV: Changes of value.

H. DDC System Provider: Authorized representative of, and trained by, DDC system manufacturer and responsible for execution of DDC system Work indicated.

I. Distributed Control: Processing of system data is decentralized and control decisions are made at subsystem level. System operational programs and information are provided to remote subsystems and status is reported back. On loss of communication, subsystems shall be capable of operating in a standalone mode using the last best available data.

J. DOCSIS: Data-Over Cable Service Interface Specifications.

K. E/P: Voltage to pneumatic.

L. Gateway: Bidirectional protocol translator that connects control systems that use different communication protocols.

M. HLC: Heavy load conditions.

N. I/O: System through which information is received and transmitted. I/O refers to analog input (AI), binary input (BI), analog output (AO) and binary output (BO). Analog signals are continuous and represent control influences such as flow, level, moisture, pressure, and temperature. Binary signals convert electronic signals to digital pulses (values) and generally represent two-position operating and alarm status. "Digital," (DI and (DO), is sometimes used interchangeably with "Binary," (BI) and (BO), respectively.

O. I/P: Current to pneumatic.

P. LAN: Local area network.
Q. LNS: LonWorks Network Services.

R. LON Specific Definitions:

1. FTT-10: Echelon Transmitter-Free Topology Transceiver.
2. LonMark: Association comprising suppliers and installers of LonTalk products. Association provides guidelines for implementing LonTalk protocol to ensure interoperability through a standard or consistent implementation.
3. LonTalk: An open standard protocol developed by the Echelon Corporation that uses a "Neuron Chip" for communication. LonTalk is a registered trademark of Echelon.
4. LonWorks: Network technology developed by Echelon.
5. Node: Device that communicates using CEA-709.1-C protocol and that is connected to a CEA-709.1-C network.
6. Node Address: The logical address of a node on the network, consisting of a Domain number, Subnet number, and Node number. "Node number" portion of an address is a number assigned to device during installation, is unique within a subnet, and is not a factory-set unique Node ID.
7. Node ID: A unique 48-bit identifier assigned at factory to each CEA-709.1-C device. Sometimes called a "Neuron ID."
8. Program ID: An identifier (number) stored in a device (usually EEPROM) that identifies node manufacturer, functionality of device (application and sequence), transceiver used, and intended device usage.
10. Standard Network Variable Type (SNVT): Pronounced "snivet." A standard format type maintained by LonMark used to define data information transmitted and received by individual nodes. "SNVT" is used in two ways. It is an acronym for "Standard Network Variable Type" and is often used to indicate a network variable itself (i.e., it can mean "a network variable of a standard network variable type").
11. Subnet: Consists of a logical grouping of up to 127 nodes, where logical grouping is defined by node addressing. Each subnet is assigned a number, which is unique within a Domain. See "Node Address."
12. TP/FT-10: Free Topology Twisted Pair network defined by CEA-709.3 and is most common media type for a CEA-709.1-C control network.
13. TP/XF-1250: High-speed, 1.25-Mbps, twisted-pair, doubly terminated bus network defined by "LonMark Interoperability Guidelines" typically used only to connect multiple TP/FT-10 networks.
14. User-Defined Configuration Property Type (UCPT): Pronounced "U-Keep-It." A Configuration Property format type that is defined by device manufacturer.
15. User-Defined Network Variable Type (UNVT): Network variable format defined by device manufacturer. UNVTs create non-standard communications that other vendors' devices may not correctly interpret and may negatively impact system operation. UNVTs are not allowed.

S. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.

T. Mobile Device: A data-enabled phone or tablet computer capable of connecting to a cellular data network and running a native control application or accessing a web interface.

V. MS/TP: Master-slave/token-passing, IEE 8802-3. Datalink protocol LAN option that uses twisted-pair wire for low-speed communication.
W. MTBF: Mean time between failures.
X. Network Controller: Digital controller, which supports a family of programmable application controllers and application-specific controllers, that communicates on peer-to-peer network for transmission of global data.
Y. Network Repeater: Device that receives data packet from one network and rebroadcasts it to another network. No routing information is added to protocol.
Z. Peer to Peer: Networking architecture that treats all network stations as equal partners.
AA. POT: Portable operator's terminal.
BB. PUE: Performance usage effectiveness.
CC. RAM: Random access memory.
DD. RF: Radio frequency.
EE. Router: Device connecting two or more networks at network layer.
FF. Server: Computer used to maintain system configuration, historical and programming database.
GG. TCP/IP: Transport control protocol/Internet protocol.
HH. UPS: Uninterruptible power supply.
II. USB: Universal Serial Bus.
JJ. User Datagram Protocol (UDP): This protocol assumes that the IP is used as the underlying protocol.
KK. VAV: Variable air volume.
LL. WLED: White light emitting diode.

1.4 PREINSTALLATION MEETINGS
A. Preinstallation Conference: Conduct conference at Project site.

1.5 ACTION SUBMITTALS
A. Multiple Submissions:
   1. If multiple submissions are required to execute work within schedule, first submit a coordinated schedule clearly defining intent of multiple submissions. Include a proposed
date of each submission with a detailed description of submittal content to be included in each submission.

2. Clearly identify each submittal requirement indicated and in which submission the information will be provided.

3. Include an updated schedule in each subsequent submission with changes highlighted to easily track the changes made to previous submitted schedule.

B. Product Data: For each type of product include the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.

2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.


4. Installation, operation and maintenance instructions including factors effecting performance.

5. Bill of materials of indicating quantity, manufacturer, and extended model number for each unique product.
   a. DDC controllers.
   b. Enclosures.
   c. Accessories.
   d. Instruments.
   e. Control dampers and actuators.
   f. Control valves and actuators.

6. When manufacturer’s product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.

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

C. Shop Drawings:

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

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

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

4. 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. Information, drawn to scale.

g. 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.

c. Control signal tubing to sensors, switches and transmitters.

d. Process signal tubing to sensors, switches and transmitters.

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. 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.

1.6 INFORMATIONAL SUBMITTALS

A. Coordination Drawings:

   1. Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

      a. Product installation location shown in relationship to room, duct, pipe and equipment.
      b. Structural members to which products will be attached.
      c. Wall-mounted instruments located in finished space showing relationship to light switches, fire-alarm devices and other installed devices.
      d. Size and location of wall access panels for products installed behind walls and requiring access.

   2. Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

      a. Ceiling components.
      b. Size and location of access panels for products installed above inaccessible ceiling assemblies and requiring access.
      c. Items penetrating finished ceiling including the following:

         1) Lighting fixtures.
         2) Air outlets and inlets.
         3) Speakers.
         4) Sprinklers.
         5) Access panels.
         6) Motion sensors.
         7) Pressure sensors.
         8) Temperature sensors and other DDC control system instruments.

B. Qualification Data:

   1. Systems Provider Qualification Data:
a. Resume of project manager assigned to Project.
b. Resumes of application engineering staff assigned to Project.
c. Resumes of installation and programming technicians assigned to Project.
d. Resumes of service technicians assigned to Project.
e. Brief description of past project including physical address, floor area, number of floors, building system cooling and heating capacity and building's primary function.
f. Description of past project DDC system, noting similarities to Project scope and complexity indicated.
g. Names of staff assigned to past project that will also be assigned to execute work of this Project.
h. Owner contact information for past project including name, phone number, and e-mail address.
i. Contractor contact information for past project including name, phone number, and e-mail address.
j. Engineer contact information for past project including name, phone number, and e-mail address.

2. Manufacturer's qualification data.
3. Testing agency's qualifications data.

C. Product Certificates:
   1. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with ASHRAE 135.

D. Product Test Reports: For each product that requires testing to be performed by manufacturer.

E. Preconstruction Test Reports: For each separate test performed.

F. Source quality-control reports.

G. Field quality-control reports.

H. Sample Warranty: For manufacturer's warranty.

1.7 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For DDC system to include in emergency, operation and maintenance manuals.
   1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
      a. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.
      b. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
      c. As-built versions of submittal Product Data.
      d. Names, addresses, e-mail addresses and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
1.8 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.

C. Furnish parts, as indicated by manufacturer’s recommended parts list, for product operation during one-year period following warranty period.

D. Furnish quantity indicated of matching product(s) in Project inventory for each unique size and type of following:
   1. Room Temperature Sensor: One.
   2. General-Purpose Relay: One.

1.9 QUALITY ASSURANCE

A. DDC System Manufacturer Qualifications:
1. Nationally recognized manufacturer of DDC systems and products.
2. DDC systems with similar requirements to those indicated for a continuous period of five years within time of bid.
3. DDC systems and products that have been successfully tested and in use on at least three past projects.
4. Having complete published catalog literature, installation, operation and maintenance manuals for all products intended for use.
5. Having full-time in-house employees for the following:
   a. Product research and development.
   b. Product and application engineering.
   c. Product manufacturing, testing and quality control.
   d. Technical support for DDC system installation training, commissioning and troubleshooting of installations.
   e. Owner operator training.

B. DDC System Provider Qualifications:
   1. Authorized representative of, and trained by, DDC system manufacturer.
   2. In-place facility located within 50 miles of Project.
   3. Demonstrated past experience with installation of DDC system products being installed for period within three consecutive years before time of bid.
   4. Demonstrated past experience on five projects of similar complexity, scope and value.
   5. Each person assigned to Project shall have demonstrated past experience.
   6. Staffing resources of competent and experienced full-time employees that are assigned to execute work according to schedule.
   7. Service and maintenance staff assigned to support Project during warranty period.
   8. Product parts inventory to support on-going DDC system operation for a period of not less than 5 years after Substantial Completion.
   9. DDC system manufacturer's backing to take over execution of Work if necessary to comply with requirements indicated. Include Project-specific written letter, signed by manufacturer's corporate officer, if requested.

C. Testing Agency Qualifications: Member company of NETA.
   1. Testing Agency’s Field Supervisor: Certified by NETA to supervise on-site testing.

1.10 WARRANTY

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

1. Failures shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.

   a. Install updates only after receiving Owner's written authorization.

3. Warranty service shall occur during normal business hours and commence within 16 hours of Owner's warranty service request.
4. Warranty Period: Two year(s) from date of Substantial Completion.
PART 2 - PRODUCTS

2.1 DDC SYSTEM MANUFACTURERS

A. Manufacturers: The DDC system shall be an extension of existing Johnson Controls Metasys provided by Johnson controls Bothell branch office. Contact pulkit.gaur@jci.com, 206-300-3674. No substitutions allowed.

2.2 DDC SYSTEM DESCRIPTION

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

1. DDC system shall consist of a high-speed, peer-to-peer network of distributed DDC controllers, other network devices, operator interfaces, and software.

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

2.3 PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design DDC system to satisfy requirements indicated.

B. Delegated Design: Engage a qualified professional to design DDC system to satisfy requirements indicated.

1. System Performance Objectives:
   a. DDC system shall manage HVAC systems.
   b. DDC system control shall operate HVAC systems to achieve optimum operating costs while using least possible energy and maintaining specified performance.
   c. DDC system shall respond to power failures, HVAC equipment failures, and adverse and emergency conditions encountered through connected I/O points.
   d. DDC system shall operate while unattended by an operator and through operator interaction.
   e. DDC system shall record trends and transaction of events and produce report information such as performance, energy, occupancies, and equipment operation.

C. Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths shall comply with ASTM E84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.

   1. Flame-Spread Index: 25 or less.
   2. Smoke-Developed Index: 50 or less.

D. DDC System Speed:
1. Response Time of Connected I/O:
   a. AI point values connected to DDC system shall be updated at least every five seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
   b. BI point values connected to DDC system shall be updated at least every five seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
   c. AO points connected to DDC system shall begin to respond to controller output commands within two second(s). Global commands shall also comply with this requirement.
   d. BO point values connected to DDC system shall respond to controller output commands within two second(s). Global commands shall also comply with this requirement.

2. Display of Connected I/O:
   a. Analog point COV connected to DDC system shall be updated and displayed at least every 10 seconds for use by operator.
   b. Binary point COV connected to DDC system shall be updated and displayed at least every 10 seconds for use by operator.
   c. Alarms of analog and digital points connected to DDC system shall be displayed within 45 seconds of activation or change of state.
   d. Graphic display refresh shall update within eight seconds.
   e. Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations shall not exceed graphic refresh rate indicated.

E. DDC System Data Storage:
   1. Include capability to archive not less than 36 consecutive months of historical data for all I/O points connected to system, including alarms, event histories, transaction logs, trends and other information indicated.

F. DDC Data Access:
   1. When logged into the system, operator shall be able to also interact with any DDC controller connected to DDC system as required for functional operation of DDC system.
   2. System(s) shall be used for application configuration; for archiving, reporting and trending of data; for operator transaction archiving and reporting; for network information management; for alarm annunciation; and for operator interface tasks and controls application management.

G. Input Point Displayed Accuracy: Input point displayed values shall meet following end-to-end overall system accuracy, including errors associated with meter, sensor, transmitter, lead wire or cable, and analog to digital conversion.
   1. Temperature, Dry Bulb:
      a. Air: Within 1 deg F.
      b. Space: Within 1 deg F.
      c. Outdoor: Within 2 deg F.
      d. Chilled Water: Within 1 deg F.
e. Heating Hot Water: Within 1 deg F.

f. Other Temperatures Not Indicated: Within 1 deg F.

H. Precision of I/O Reported Values: Values reported in database and displayed shall have following precision:

1. Current:
   a. Milliamperes: Nearest 1/100th of a milliampere.
   b. Amperes: Nearest 1/10th of an ampere up to 100 A; nearest ampere for 100 A and more.

2. Position, Dampers and Valves (Percentage Open): Nearest 1 percent.

3. Pressure:
   a. Air, Ducts and Equipment: Nearest 1/10th in. w.c..
   b. Water: Nearest 1/10 psig through 100 psig; nearest psig above 100 psig.

4. Temperature:
   a. Air, Ducts and Equipment: Nearest 1/10th of a degree.
   b. Outdoor: Nearest degree.
   c. Space: Nearest 1/10th of a degree.
   d. Chilled Water: Nearest 1/10th of a degree.
   e. Heating Hot Water: Nearest degree.

5. Voltage: Nearest 1/10 volt up to 100 V; nearest volt above 100 V.

6. Temperature, Dry Bulb:
   a. Air: Within 2 deg F.
   b. Space: Within 2 deg F.
   c. Chilled Water: Within 1 deg F.
   d. Heating Hot Water: Within 2 deg F.

I. Environmental Conditions for Controllers, Gateways, and Routers:

1. Products shall operate without performance degradation under ambient environmental temperature, pressure and humidity conditions encountered for installed location.
   a. If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, cooled and ventilated as required by product and application.

2. Products shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Products not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:
   a. Indoors, Heated with Filtered Ventilation: Type 1.
   b. Indoors, Heated and Air Conditioned: Type 1.
3. Instruments and actuators shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.

   a. If instruments and actuators alone cannot comply with requirement, install instruments and actuators in protective enclosures that are isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated and ventilated as required by instrument and application.

4. Instruments, actuators and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments and actuators not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:

   a. Indoors, Heated with Filtered Ventilation: Type 1.
   b. Indoors, Heated and Air-conditioned: Type 1.

2.4 DDC CONTROLLERS

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

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

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

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

E. Environment Requirements:

   1. Controller hardware shall be suitable for the anticipated ambient conditions.
   2. Controllers located in conditioned space shall be rated for operation at 32 to 120 deg F.

F. DDC Controller Spare Processing Capacity:

   1. Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:
      a. Application-Specific Controllers: Not less than 70 percent.

   2. Memory shall support DDC controller's operating system and database and shall include the following:
      a. Monitoring and control.
b. Energy management, operation and optimization applications.
c. Alarm management.
d. Historical trend data of all connected I/O points.
e. Maintenance applications.
f. Operator interfaces.
g. Monitoring of manual overrides.

G. DDC Controller Spare I/O Point Capacity: Include spare I/O point capacity for each controller as follows:

1. Programmable Application Controllers:
   a. 10 percent of each AI, AO, BI, and BO point connected to controller.
   b. Minimum Spare I/O Points per Controller:
      1) AIs: Two.
      2) AOs: Two.
      3) BIs: Three.
      4) BOs: Three.

2. Application-Specific Controllers:
   a. 10 percent of each AI, AO, BI, and BO point connected to controller.
   b. Minimum Spare I/O Points per Controller:
      1) AIs: One.
      2) AOs: One.
      3) BIs: One.
      4) BOs: One.

H. Maintenance and Support: Include the following features to facilitate maintenance and support:

1. Mount microprocessor components on circuit cards for ease of removal and replacement.
2. Means to quickly and easily disconnect controller from network.
3. Means to quickly and easily access connect to field test equipment.
4. Visual indication that controller electric power is on, of communication fault or trouble, and that controller is receiving and sending signals to network.

2.5 PROGRAMMABLE APPLICATION CONTROLLERS

A. General Programmable Application Controller Requirements:

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

7. Controllers shall be fully programmable.

B. Communication:

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

C. Operator Interface:

1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation or mobile device.
2. Local Keypad and Display:
   a. Equip controller with local keypad and digital display for interrogating and editing data.
   b. Use of keypad and display shall require security password.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

2.6 APPLICATION-SPECIFIC CONTROLLERS

A. Description: Microprocessor-based controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment. Controllers are not fully user-programmable but are configurable and customizable for operation of equipment they are designed to control.

1. Capable of standalone operation and shall continue to include control functions without being connected to network.
2. Data shall be shared between networked controllers and other network devices.

B. Communication: Application-specific controllers shall communicate with other application-specific controller and devices on network, and to programmable application and network controllers.

C. Operator Interface: Controller shall be equipped with a service communications port for connection to a portable operator's workstation. Connection shall extend to port on space temperature sensor that is connected to controller.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall use nonvolatile memory and maintain all BIOS and programming information in event of power loss.

2.7 CONTROLLER SOFTWARE

A. General Controller Software Requirements:

1. Software applications shall reside and operate in controllers. Editing of applications shall occur at operator workstations.
2. I/O points shall be identified by up to 30-character point name and up to 16-character point descriptor. Same names shall be used at operator workstations.
3. Control functions shall be executed within controllers using DDC algorithms.
4. Controllers shall be configured to use stored default values to ensure fail-safe operation. Default values shall be used when there is a failure of a connected input instrument or loss of communication of a global point value.

B. Security:

1. Operator access shall be secured using individual security passwords and user names.
2. Passwords shall restrict operator to points, applications, and system functions as assigned by system manager.
3. Operator log-on and log-off attempts shall be recorded.
4. System shall protect itself from unauthorized use by automatically logging off after last keystroke. The delay time shall be operator-definable.

C. Scheduling: Include capability to schedule each point or group of points in system. Each schedule shall consist of the following:

1. Weekly Schedule:
   a. Include separate schedules for each day of week.
   b. Each schedule should include the capability for start, stop, optimal start, optimal stop, and night economizer.
   c. Each schedule may consist of up to 10 events.
   d. When a group of objects are scheduled together, include capability to adjust start and stop times for each member.

2. Exception Schedules:
   a. Include ability for operator to designate any day of the year as an exception schedule.
   b. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by regular schedule for that day of week.

3. Holiday Schedules:
   a. Include capability for operator to define up to 99 special or holiday schedules.
   b. Schedules may be placed on scheduling calendar and will be repeated each year.
c. Operator shall be able to define length of each holiday period.

D. System Coordination:
   1. Include standard application for proper coordination of equipment.
   2. Application shall include operator with a method of grouping together equipment based on function and location.
   3. Group may then be used for scheduling and other applications.

E. Binary Alarms:
   1. Each binary point shall be set to alarm based on operator-specified state.
   2. Include capability to automatically and manually disable alarming.

F. Analog Alarms:
   1. Each analog object shall have both high and low alarm limits.
   2. Alarming shall be able to be automatically and manually disabled.

G. Alarm Reporting:
   1. Operator shall be able to determine action to be taken in event of an alarm.
   2. Alarms shall be routed to appropriate operator workstations based on time and other conditions.
   3. Alarm shall be able to start programs, print, be logged in event log, generate custom messages, and display graphics.

2.8 ENCLOSURES

A. General Enclosure Requirements:
   1. House each controller and associated control accessories in a single enclosure. Enclosure shall serve as central tie-in point for control devices such as switches, transmitters, transducers, power supplies and transformers.
   2. Do not house more than one controller in a single enclosure.
   3. Include enclosure door with key locking mechanism. Key locks alike for all enclosures and include one pair of keys per enclosure.
   4. Equip doors of enclosures housing controllers and components with analog or digital displays with windows to allow visual observation of displays without opening enclosure door.
   5. Individual wall-mounted single-door enclosures shall not exceed 36 inches wide and 48 inches high.

B. Combination On-Off Status Sensor and On-Off Relay:
   1. Manufacturers: Subject to compliance with requirements, provide products by the following:
      a. Functional Devices Inc.
   2. Description:
2.9 CONTROL WIRE AND CABLE

A. Single Twisted Shielded Instrumentation Cable above 24 V:

1. Wire size shall be a minimum No. 18 AWG.
2. Conductors shall be a twisted, 7/24 soft annealed copper strand with a 2- to 2.5-inch lay.
3. Conductor insulation shall have a Type THHN/THWN or Type TFN rating.
4. Shielding shall be 100 percent type, 0.35/0.5-mil aluminum/Mylar tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
5. Outer jacket insulation shall have a 600-V, 90-deg C rating and shall be Type TC cable.
6. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red and white.
7. Furnish wire on spools.

B. Single Twisted Shielded Instrumentation Cable 24 V and Less:

1. Wire size shall be a minimum No. 18 AWG.
2. Conductors shall be a twisted, 7/24 soft annealed copper stranding with a 2- to 2.5-inch lay.
3. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame-retardant PVC.
4. Shielding shall be 100 percent type, 1.35-mil aluminum/polymer tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
5. Outer jacket insulation shall have a 300-V, 105-deg C rating and shall be Type PLTC cable.
6. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red and white.
7. Furnish wire on spools.

2.10 ACCESSORIES

A. Damper Blade Limit Switches:

1. Sense positive open and/or closed position of the damper blades.
2. NEMA 250, Type 13, oil-tight construction.
3. Arrange for the mounting application.
4. Additional waterproof enclosure when required by its environment.
5. Arrange to prevent "over-center" operation.

B. Manual Valves:

1. Ball Type:
   a. Manufacturers: Subject to compliance with requirements, provide products by the following:
      1) NIBCO INC.
   c. Ball: Type 316 stainless steel.
   d. Stem: Type 316 stainless steel.
   e. Seats: Reinforced PTFE.
   f. Packing Ring: Reinforced PTFE.
   g. Lever: Stainless steel with a vinyl grip.
   h. 600 WOG.
   i. Threaded end connections.

2.11 IDENTIFICATION

A. Control Equipment, Instruments, and Control Devices:

   a. Include instruments with unique identification identified by equipment being controlled or monitored, followed by point identification.

2. Letter size shall be as follows:
   a. Accessories: Minimum of 0.25 inch Insert dimension high.
   b. Instruments: Minimum of 0.25 inch Insert dimension high.
   c. Control Damper and Valve Actuators: Minimum of 0.25 inch Insert dimension high.

3. Legend shall consist of white lettering on black background.
4. Laminated acrylic or melamine plastic sign shall be engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers are color-coded black with contrasting white center exposed by engraving through outer layer and shall be fastened with drive pins.

5. Instruments, control devices and actuators with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require additional identification.

B. Valve Tags:

1. Brass tags and brass chains attached to valve.
2. Tags shall be at least 1.5 inches in diameter.
3. Include tag with unique valve identification indicating control influence such as flow, level, pressure, or temperature; followed by location of valve, and followed by three-digit sequential number. For example: TV-1.001.
4. Valves with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require an additional tag.

C. Equipment Warning Labels:

1. Self-adhesive label with pressure-sensitive adhesive back and peel-off protective jacket.
2. Lettering size shall be at least 14-point type with white lettering on red background.
3. Warning label shall read “CAUTION-Equipment operated under remote automatic control and may start or stop at any time without warning. Switch electric power disconnecting means to OFF position before servicing.”
4. Lettering shall be enclosed in a white line border. Edge of label shall extend at least 0.25 inch beyond white border.

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. Fan-coil units specified in Section 238219 "Fan Coil Units."

3.3 DDC SYSTEM INTERFACE WITH EXISTING SYSTEMS

A. Interface with Existing Systems:
   1. DDC systems shall interface existing systems to achieve integration.
   2. Monitoring and Control of DDC System by Existing Control System:
      a. DDC system performance requirements shall be satisfied when monitoring and controlling DDC system by existing control system.
      b. Operator of existing system shall be able to upload, download, monitor, trend, control and program every input and output point in DDC system from existing control system using existing control system software and operator workstations.
      c. Remote monitoring and control from existing control system shall not require operators of existing control system to learn new software.
      d. Interface of DDC system into existing control system shall be transparent to operators of existing control system and allow operators to program, monitor, and control DDC system from any operator workstation connected to existing control system.

B. Integration with Existing Enterprise System:
   1. DDC system shall interface with an existing enterprise system to adhere to Owner standards already in-place and to achieve integration.
   2. Owner's control system integrator will provide the following services:
      a. Enterprise system expansion and development of graphics, logs, reports, trends and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
      b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.
      c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.
   3. Engage Owner's control system integrator to provide the following services:
      a. Enterprise system expansion and development of graphics, logs, reports, trends and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.

c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.

4. Attend meetings with control system integrator to integrate DDC system.

3.4 CONTROL DEVICES FOR INSTALLATION BY INSTALLERS

A. Deliver selected control devices, specified in indicated HVAC instrumentation and control device Sections, to identified equipment and systems manufacturers for factory installation and to identified installers for field installation.

B. Deliver the following to duct fabricator and Installer for installation in ductwork. Include installation instructions to Installer and supervise installation for compliance with requirements.

1. DDC control dampers, which are specified in Section 230923.12 "DDC Control Dampers."

C. Deliver the following to plumbing and HVAC piping installers for installation in piping. Include installation instructions to Installer and supervise installation for compliance with requirements.

1. DDC control valves, which are specified in Section 230923.11 "Control Valves."
2. Pipe-mounted flow meters, which are specified in Section 230923.14 "Flow Instruments."
3. Pipe-mounted sensors, switches and transmitters. Flow meters are specified in Section 230923.14 "Flow Instruments." Liquid temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
4. Pipe- and tank-mounted thermowells. Liquid thermowells are specified in Section 230923.27 "Temperature Instruments."

3.5 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. If codes and referenced standards are more stringent than requirements indicated, comply with requirements in codes and referenced standards.

D. 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.

E. Firestop Penetrations Made in Fire-Rated Assemblies: Comply with requirements in Section 078413 "Penetration Firestopping."

F. Seal penetrations made in acoustically rated assemblies. Comply with requirements in Section 079200 "Joint Sealants."

G. 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.

H. 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.

3.6 ENCLOSURES INSTALLATION

A. Install the following items in enclosures, to comply with indicated requirements:
   1. Controllers.

B. Attach wall-mounted enclosures to wall using the following types of steel struts:
   1. For NEMA 250, Type 1 Enclosures: Use painted steel strut and hardware.

3.7 CONTROL WIRE, CABLE AND RACEWAYS INSTALLATION

A. Comply with NECA 1.

B. Wire and Cable Installation:
   1. 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.
   2. 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.
   3. Terminate field wiring and cable not directly connected to instruments and control devices having integral wiring terminals using terminal blocks.
   4. Install signal transmission components according to IEEE C2, REA Form 511a, NFPA 70, and as indicated.
   5. Use shielded cable to transmitters.
   6. Use shielded cable to temperature sensors.
   7. Perform continuity and meager testing on wire and cable after installation.
3.8 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. Verify that control dampers are installed correctly for flow direction.
   2. Verify that proper blade alignment, either parallel or opposed, has been provided.
   3. Verify that damper frame attachment is properly secured and sealed.
   4. Verify that damper actuator and linkage attachment is secure.
   5. Verify that actuator wiring is complete, enclosed and connected to correct power source.
   6. Verify that damper blade travel is unobstructed.

G. Control Valve Checkout:
   1. Verify that control valves are installed correctly for flow direction.
   2. Verify that valve body attachment is properly secured and sealed.
   3. Verify that valve actuator and linkage attachment is secure.
   4. Verify that actuator wiring is complete, enclosed and connected to correct power source.
   5. Verify that valve ball, disc or plug travel is unobstructed.
   6. 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.
3.9 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. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

3.10 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.

3.11 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 desire results.

3.12 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.
3.13 FINAL REVIEW

A. Submit written request to 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 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 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 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 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 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 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. 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.

s. Insert additional requirements.

3.14 ADJUSTING

A. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

3.15 MAINTENANCE SERVICE

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

3.16 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 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 separate training classes.
   d. Each training class shall be not less than one consecutive day(s).

C. Training Schedule:

1. Schedule training with Owner 20 business days before expected Substantial Completion.
2. Schedule training to provide Owner with at least 10 business days of notice in advance of training.
3. 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 five attendees.
2. Make allowance for Owner to add up to two 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. 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.

G. Instructor Requirements:
1. One or multiple qualified instructors, as required, to provide training.
2. Instructors shall have not less than five years of providing instructional training on not less than five past projects with similar DDC system scope and complexity to DDC system installed.

H. 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.

I. Training Outline:
1. Submit training outline for Owner review at least 10 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.

J. 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.

K. Training Content for Daily Operators:
1. Basic operation of system.
2. Understanding each unique product type installed including performance and service requirements for each.
3. Understanding operation of each system and equipment controlled by DDC system including sequences of operation, each unique control algorithm and each unique optimization routine.

4. Accessing data from DDC controllers.

5. Executing digital and analog commands in graphic mode.

6. Demonstrating control loop precision and stability via trend logs of I/O for not less than 10 percent of I/O installed.

7. Demonstrating DDC system performance through trend logs and command tracing.

8. Demonstrating scan, update, and alarm responsiveness.


10. Demonstrating on-line user guide, and help function and mail facility.

11. 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. Sharing of previously graphed trends of all control loops to demonstrate that each control loop is stable and set points are being maintained.

L. 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 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