MasterSpec 03/16

SECTION 23 09 23
DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

TIPS:

To view non-printing **Editor's Notes** that provide guidance for editing, click on MasterWorks/Single-File Formatting/Toggle/Editor's Notes, or the Paragraph symbol in the HOME tab of the Word toolbar.

To read **detailed research, technical information about products and materials, and coordination checklists**, click on MasterWorks/Supporting Information.

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

MANDATORY REQUIREMENT: Retain this article in all Sections of Project Manual.

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.

Coordinate subparagraph below with "Control Devices for Installation by Installers" and "Control Devices for Equipment Manufacturer Factory Installation" articles.

2. Delivery of selected control devices to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.
3. Description: System software shall be based on a server/thin-client architecture, designed around the open standards of web technology. The control system server shall be accessed using a Web browser over the control system network, the District's local area network, and (at the District's discretion) over the Internet.

The intent of the thin-client architecture is to provide operators complete access to the control system via a Web browser. No special software other than a web browser shall be required to access graphics, point displays, trends, configure trends, configure points and controllers, or to download programming into the controllers.

B. Related Requirements:

Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

1. Section 23 09 23.13 "Energy Meters" for thermal and electric power energy meters that connect to DDC systems.
2. Section 23 09 23.33 "Vibration Instruments" for vibration instruments that connect to DDC systems.
3. Section 23 09 23.43 "Weather Stations" for weather stations that connect to DDC systems. Communications Cabling:

    a. Section 260523 "Control-Voltage Electrical Power Cables" for balanced twisted pair communications cable.
    b. Section 271513 "Communications Copper Horizontal Cabling" for balanced twisted pair communications cable.
    c. Section 271523 "Communications Optical Fiber Horizontal Cabling" for optical fiber communications cable.

4. 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.

5. Section 260553 "Identification for Electrical Systems" for identification requirements for electrical components.
6. Section 270553 "Identification for Communications Systems" for identification requirements for communications components.

1.3 DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

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:

1. BACnet: Building Automation Control Network Protocol, ASHRAE 135. A communications protocol allowing devices to communicate data over and services over a network.
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.
4. BACnet Testing Laboratories (BTL): Organization responsible for testing products for compliance with ASHRAE 135, operated under direction of BACnet International.
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. COV: Changes of value.

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

H. 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.

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

J. HDMI: High Definition Multimedia Interface

K. HLC: Heavy load conditions.

L. 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.

M. LAN: Local area network.

N. 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.

O. MS/TP: Master-slave/token-passing, IEE 8802-3. Datalink protocol LAN option that uses twisted-pair wire for low-speed communication.

P. MTBF: Mean time between failures.

Q. 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.

R. Peer to Peer: Networking architecture that treats all network stations as equal partners.

S. RAM: Random access memory.

T. RF: Radio frequency.

U. Router: Device connecting two or more networks at network layer.

V. Server: Computer used to maintain system configuration, historical and programming database.

W. USB: Universal Serial Bus.

X. UDP: User Datagram Protocol. This protocol assumes that the IP is used as the underlying protocol.

Y. VAV: Variable air volume.

Z. VM: Virtual Machine

AA. WLED: White light emitting diode.

1.4 PRESUBMITTAL MEETING

A. Presubmittal Conference

1. Conduct conference within one month after Notice To Proceed
2. Coordinate with District Construction Manager.
3. Conduct conference at District Physical Plant Operations Facility.
4. Attendees, in addition to those specified in Section 01 31 00 “Project Management”:

a. Project Architect.
b. Project Mechanical Engineer.
c. District Commissioning Agent.
d. Mechanical systems representative(s) from District Physical Plant Operations and Facilities Planning and Construction Departments.

5. Agenda items shall include:
   a. District standards for software and graphics, including any proposed deviations.
   b. Sequence of operation. Clearly identify all proposed deviations from specified sequence of operation.
   c. Required software to be installed on District server.
   d. Sample graphics, including any proposed deviations.
   e. Deviations from specified sequence of operation.
   f. Potential problems. Clearly identify all potential problems.
6. Do not commence submittal preparation until all parties agree to graphics, sequence of operations, and required software.

1.5 PREINSTALLATION MEETINGS

A. Preinstallation Conference:

1. Coordinate with District Construction Manager.
2. Conduct conference at District Physical Plant Operations Facility.
3. Attendees, in addition to those specified in Section 01 31 00 “Project Management”:
   a. Project Architect
   b. Project Mechanical Engineer
   c. Mechanical systems representative(s) from District Physical Plant Operations and Facilities Planning and Construction Departments.

If needed, insert additional conference participants not mentioned in Section 01 31 00 "Project Management and Coordination."

1.6 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.
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, DDC system manufacturer, and extended model number for each unique product.

Subparagraphs below are only examples of products to include.

a. Operator workstations.
b. Servers.
c. Printers.
d. Gateways.
e. Routers.
f. Protocol analyzers.
g. DDC controllers.
h. Enclosures.
i. Electrical power devices.
j. Accessories.
k. Instruments.
l. Control dampers and actuators.
m. Control valves and actuators.
n. <**Insert product**>.

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. Software Submittal:

1. Cross-referenced listing of software to be loaded on each operator workstation, gateway,<**Insert product**> and DDC controller, to verify software functions properly on operator workstation, and on District server.
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, 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.

D. Shop Drawings:

1. Include plans, elevations, sections, and mounting details where applicable.
2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Detail means of vibration isolation and show attachments to rotating equipment.
4. Plan Drawings indicating the following:

    a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork and piping.
    b. Room names and numbers with coordinated placement to avoid interference with control products indicated.
    c. Each desktop operator 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, of <**Insert requirements**>.

5. Schematic drawings for each controlled HVAC system indicating the following:

    a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
    b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.
    c. A graphic showing location of control I/O in proper relationship to HVAC system.
    d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
    e. Unique identification of each I/O that shall be consistently used between different drawings showing same point.

f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays and interface to DDC controllers.
g. Narrative sequence of operation.
h. Graphic sequence of operation, showing all inputs and output logical blocks.

6. Control panel drawings indicating the following:

a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates and allocated spare space.
c. Unique drawing for each panel.

7. DDC system network riser diagram indicating the following:

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

8. DDC system electrical power riser diagram indicating the following:

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

9. Monitoring and control signal diagrams indicating the following:

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

10. Color graphics indicating the following:

a. Do not commence submittal preparation until all parties agree to graphics, sequence of operations, and required software.
b. Itemized list of color graphic displays to be provided.

c. For each display screen to be provided, a true color copy showing layout of pictures, graphics and data displayed.
d. Intended operator access between related hierarchical display screens.
e. Within one month of submittal approval, provide a print out of all proposed graphics for review by Project Architect, Project Engineer, District Commissioning Agent, and Mechanical systems representative(s) from District Physical Plant Operations and Facilities Planning and Construction Departments.

E. 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:

a. Loss of power.
b. Loss of network communication signal.
c. Loss of controller signals to inputs and outpoints.
d. Operator workstation failure.
e. Server failure.
f. Gateway failure.
g. Network failure
h. Controller failure.
i. Instrument failure.
j. Control damper and valve actuator failure.
k. <**Insert potential failure conditions**>.

4. Complete bibliography of documentation and media to be delivered to District.
5. Description of testing plans and procedures.
6. Description of District training.

1.7 INFORMATIONAL SUBMITTALS

Coordinate "Qualification Data" Paragraph below with qualification requirements in "Quality Assurance" Article.

A. Qualification Data:

1. DDC system manufacturer’s qualification data.
2. DDC system provider’s qualification data.
3. Testing agency's qualifications data.

Retain "Welding certificates" Paragraph below if retaining "Welding Qualifications" Paragraph in "Quality Assurance" Article.

B. Welding certificates.

Retain "Product Certificates" Paragraph below to require submittal of product certificates from DDC system manufacturer.

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. Field quality-control reports.

F. Sample Warranty
1. For manufacturers and DDC System Provider warranty.
2. See Part 1 article “Warranty” and Part 3 article “Control Devices for Equipment Manufacturer Factory Installation” for additional information.

1.8 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 01 78 23 "Operation and Maintenance Data," include the following:

a. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.
b. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
c. As-built versions of submittal Product Data.
d. Names, addresses, e-mail addresses and 24-hour telephone numbers of installer and service representatives for DDC system and products.
e. Operator's manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control and changing set points and variables.
f. Programming manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
g. Engineering, installation, and maintenance manuals that explain how to:

1) Design and install new points, panels, and other hardware.
2) Perform preventive maintenance and calibration.
3) Debug hardware problems.
4) Repair or replace hardware.

h. Documentation of all programs created using custom programming language including set points, tuning parameters, and object database.
i. Backup copy of graphic files, programs, and database on electronic media such as DVDs.
j. List of recommended spare parts with part numbers and suppliers.
k. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
l. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
m. Licenses 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. District training materials, including training software, electronic training files, etc.

1.9 MAINTENANCE MATERIAL SUBMITTALS

A. Include DDC system manufacturers' recommended parts lists for proper system operation.

1.10 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 five past projects in an educational environment.
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. If a product vendor is not the product manufacturer, vendor shall retain services of product manufacturer’s technical representative.
d. Technical support for DDC system installation training, commissioning and troubleshooting of installations.
e. District operator training.

B. DDC System Provider Qualifications:

1. Authorized representative of, and trained by, DDC system manufacturer.
2. In-place facility located within one hour travel time of Project.
3. Demonstrated past experience with installation of DDC system products being installed for period within five 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.

Retain "Testing Agency Qualifications" Paragraph below.

C. Testing Agency Qualifications: Member company of NETA.

1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

1.11 WARRANTY

A. Manufacturer's Warranty: Manufacturer and DDC System Provider 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 District.
2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.

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

3. Warranty service shall occur during normal business hours and commence within 24 hours of District's warranty service request.
4. Warranty Period: Two years from date of Substantial Completion.

    a. For Gateway: Three-year parts and labor warranty for each.

B. See additional warranty requirements at Part 3 Article “Control Devices for Equipment Manufacturer Factory Installation/Coordination”.

PART 2 - PRODUCTS

For small remodel projects where the scope is limited to a few rooms, discuss with District Project Manager option to limit specification to controls by the DDC system manufacturer of the existing on-site controls.

2.1 DDC SYSTEM MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Automated Logic Corporation.
2. Carrier I-Vu.
3. Distech Controls Inc.
4. Honeywell International, Inc.
5. Johnson Controls.
6. Trane, Inc.
7. Viconics Technologies, Inc..
8. Or Equal.

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. All required software shall reside on District server and shall be owned by District

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 WEB ACCESS

A. DDC system shall be Web compatible.

1. Access to DDC System:

a. [**Operator workstation**] [**and**] [**or**] [**server**] shall perform overall system supervision and configuration, graphical user interface, management report generation, and alarm annunciation.

b. DDC system shall support Web browser access to building data. Operator using a standard Web browser shall be able to access control graphics and change adjustable set points.
c. Web access shall be password protected. Assign each operator an access level to restrict access to data, and to functions that the operator is capable of performing.

2.4 PERFORMANCE REQUIREMENTS

A. Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths shall comply with ASTM E 84; 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.

B. DDC System Speed:

1. Response Time of Connected I/O:

First option in subparagraphs below is taken from ASHRAE's Guideline 13.

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 30 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 operator workstation to operator workstation when multiple operators are viewing from multiple operator workstations shall not exceed graphic refresh rate indicated.

C. Network Bandwidth: Design each network of DDC system to include at least 30 percent available spare bandwidth with DDC system operating under normal and heavy load conditions indicated. Calculate bandwidth usage, and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions.

Retain "DDC System Data Storage" Paragraph below to provide DDC system data archived storage over an extended operating period.

D. DDC System Data Storage:

1. Include capability to archive not less than 24 consecutive months of historical data for all I/O points connected to system, including alarms, event histories, transaction logs, trends and other information indicated.
2. Local Storage: Provide operator workstation with data storage indicated for software function testing. Server(s) shall use IT industry standard database platforms and be capable of functions described in "DDC Data Access" paragraph.
3. Cloud Storage: Provide [**application-based**] [**and**] [**web browser**] interfaces to configure, upload, download, and manage data, and service plan with storage capacity adequate to store all data for term indicated. Cloud storage shall use IT industry standard database platforms and be capable of functions described in "DDC Data Access" paragraph.

Retain "DDC Data Access" paragraph below for systems using local data storage or systems that store information locally and on the cloud. Change terminology as required. Coordinate with "Servers" Article in Part 2.

E. 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.

F. Future Expandability:

1. DDC system size shall be expandable to an ultimate capacity of at least two times total I/O points indicated.
2. Additional DDC controllers, I/O and associated wiring shall be all that is needed to achieve ultimate capacity. Initial network infrastructure shall be designed and installed to support ultimate capacity.
3. Operator interfaces installed initially shall not require hardware and software additions and revisions for ultimate capacity.

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.

Coordinate values used in subparagraphs below with accuracy of instruments specified in related sections. Values below cannot be better than other values used elsewhere.

1. Energy:

   a. Thermal: Within 5 percent of reading.
   b. Electric Power: Within 1 percent of reading.
   c. Requirements indicated on Drawings for meters not supplied by utility.

2. Flow:

   a. Air: Within 5 percent of design flow rate.
   b. Air (Terminal Units): Within 10 percent of design flow rate.
   c. Water: Within 2 percent of design flow rate.

3. Gas:

   a. Carbon Dioxide: Within 50 ppm.
   b. Carbon Monoxide: Within 5 percent of reading.
   c. Refrigerant: Within 50 ppm.

4. Moisture (Relative Humidity):

   a. Air: Within 5 percent RH.
   b. Space: Within 5 percent RH.
   c. Outdoor: Within 5 percent RH.

5. Pressure:

   a. Air, Ducts and Equipment: 1 percent of instrument range.
   b. Water: Within 1 percent of instrument range.
   c. Space: Within 1 percent of instrument range.

6. Temperature, Dew Point:

   a. Air: Within 1 deg F.
   b. Space: Within 1 deg F.
   c. Outdoor: Within 3 deg F.

7. 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. Condenser Water: Within 1 deg F.
f. Heating Hot Water: Within 1 deg F.
g. Energy Recovery Runaround Liquid: Within 1 deg F.
h. Temperature Difference: Within 0.25 deg F.
i. Other Temperatures Not Indicated: Within 1 deg F.

8. Temperature, Wet Bulb:

a. Air: Within 1 deg F.
b. Space: Within 1 deg F.
c. Outdoor: Within 2 deg F.

9. Vibration: Within 5 percent of reading.

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. Energy:

a. Electric Power:

1) Rate (Watts): Nearest 1/10th of a watt through 1000 W.
2) Rate (Kilowatts): Nearest 1/10th of a kilowatt through 1000 kW; nearest kilowatt above 1000 kW.
3) Usage (Kilowatt-Hours): Nearest kilowatt through 10,000 kW; nearest 10 kW between 10,000 and 100,000 kW; nearest 100 kW for above 100,000 kW.

b. Thermal, Rate:

1) Heating: For Btu/h, nearest Btu/h up to 1000 Btu/h; nearest 10 Btu/h between 1000 and 10,000 Btu/h; nearest 100 Btu/h for above 10,000 Btu/h. For Mbh, round to nearest Mbh up to 1000 Mbh; nearest 10 Mbh between 1000 and 10,000 Mbh; nearest 100 Mbh above 10,000 Mbh.
2) Cooling: For tons, nearest ton up to 1000 tons; nearest 10 tons between 1000 and 10,000 tons; nearest 100 tons above 10,000 tons.

c. Thermal, Usage:

1) Heating: For Btu, nearest Btu up to 1000 Btu; nearest 10 Btu between 1000 and 10,000 Btu; nearest 100 Btu for above 10,000 Btu. For Mbtu, round to nearest Mbtu up to 1000 Mbtu; nearest 10

Mbtu between 1000 and 10,000 Mbtu; nearest 100 Mbtu above 10,000 Mbtu.

2) Cooling: For ton-hours, nearest ton-hours up to 1000 ton-hours; nearest 10 ton-hours between 1000 and 10,000 ton-hours; nearest 100 tons above 10,000 tons.

3. Flow:

   a. Air: Nearest 1/10th of a cfm through 100 cfm; nearest cfm between 100 and 1000 cfm; nearest 10 cfm between 1000 and 10,000 cfm; nearest 100 cfm above 10,000 cfm.
   b. Water: Nearest 1/10th gpm through 100 gpm; nearest gpm between 100 and 1000 gpm; nearest 10 gpm between 1000 and 10,000 gpm; nearest 100 gpm above 10,000 gpm.

4. Gas:

   a. Carbon Dioxide (ppm): Nearest ppm.
   b. Carbon Monoxide (ppm): Nearest ppm.
   c. Refrigerant (ppm): Nearest ppm.

5. Moisture (Relative Humidity):

   a. Relative Humidity (Percentage): Nearest 1 percent.

6. Speed:

   a. Rotation (rpm): Nearest 1 rpm.
   b. Velocity: Nearest 1/10th fpm through 100 fpm; nearest fpm between 100 and 1000 fpm; nearest 10 fpm above 1000 fpm.

7. Position, Dampers and Valves (Percentage Open): Nearest 1 percent.
8. 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.

9. 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. Condenser Water: Nearest 1/10th of a degree.
   f. Heating Hot Water: Nearest degree.
   g. Heat Recovery Runaround: Nearest 1/10th of a degree.

10. Vibration: Nearest 1/10th in/s.
11. Voltage: Nearest 1/10 volt up to 100 V; nearest volt above 100 V.

I. Control Stability: Control variables indicated within the following limits:

Coordinate values used in subparagraphs below with values used in "Input Point Displayed Accuracy" Paragraph in this article and with accuracy of instruments specified in related sections. Values below cannot be better than other values used elsewhere.

1. Flow:

   a. Air, Ducts and Equipment, except Terminal Units: Within 5 percent of design flow rate.
   b. Air, Terminal Units: Within 10 percent of design flow rate.
   c. Water: Within 2 percent of design flow rate.

2. Gas:

   a. Carbon Dioxide: Within 50 ppm.
   b. Carbon Monoxide: Within 5 percent of reading.

3. Moisture (Relative Humidity):

   a. Air: Within 5 percent RH.
   b. Space: Within 5 percent RH.
   c. Outdoor: Within 5 percent RH.

4. Pressure:

   a. Air, Ducts and Equipment: 1 percent of instrument range.
   b. Water: Within 1 percent of instrument range.

5. Temperature, Dew Point:

   a. Air: Within 1 deg F.
   b. Space: Within 1 deg F.

6. Temperature, Dry Bulb:

   a. Air: Within 2 deg F.
   b. Space: Within 2 deg F.
   c. Chilled Water: Within 1 deg F.
   d. Condenser Water: Within 1 deg F.
   e. Heating Hot Water: Within 2 deg F.
   f. Energy Recovery Runaround Liquid: Within 1 deg F.

7. Temperature, Wet Bulb:

   a. Air: Within 1 deg F.
   b. Space: Within 1 deg F.

J. 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. Outdoors, Protected: Type 3.
    b. Outdoors, Unprotected: Type 4.
    c. Indoors, Heated and Air Conditioned: Type 1.
    d. Mechanical Equipment Rooms:

        1) Chiller and Boiler Rooms: Type 12.

    e. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 2.
    f. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: Type 4.
    g. <**Insert location and enclosure requirements**>.

K. Environmental Conditions for Instruments and Actuators:

1. 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[**, cooled**] and ventilated as required by instrument and application.

2. 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. Outdoors, Protected: [**Type 2**] [**Type 3**] [**Type 12**] <**Insert type**>.
    b. Outdoors, Unprotected: [**Type 4**] [**Type 4X**].

c. Indoors, Heated and Air-conditioned: [**Type 1**] <**Insert type**>.
d. Mechanical Equipment Rooms:

1) Chiller and Boiler Rooms: [**Type 12**] [**Type 4**] [**Type 4X**] <**Insert type**>.

e. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: [**Type 2**] [**Type 3**] [**Type 12**] <**Insert type**>.
f. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: [**Type 4**] [**Type 4X**] <**Insert type**>.
g. Hazardous Locations: Explosion-proof rating for condition.
h. **<Insert location and enclosure requirements>**.

Retain "DDC System Reliability" Paragraph below for projects with critical reliability requirements. Verify with District Project Manager if Project includes critical facilities as defined in CBC..

L. DDC System Reliability:

1. Design, install and configure DDC controllers, [**gateways,**] [**routers,**] [**and**] **<Insert product>** to yield a MTBF of at least [**40,000**] [**20,000**] **<Insert number>** hours, based on a confidence level of at least [**90**] **<Insert number>** percent. MTBF value shall include any failure for any reason to any part of products indicated.
2. If required to comply with MTBF indicated, include DDC system and product redundancy to maintain DDC system, and associated systems and equipment that are being controlled, operational and under automatic control.
3. Critical systems and equipment that require a higher degree of DDC system redundancy than MTBF indicated shall be indicated on Drawings.

Retain "Electric Power Quality" Paragraph below for applications requiring additional protection.

M. Electric Power Quality:

1. Power-Line Surges:

a. Protect [**susceptible**]DDC system products connected to ac power circuits from power-line surges to comply with requirements of IEEE C62.41.
b. Do not use fuses for surge protection.
c. Test protection in the normal mode and in the common mode, using the following two waveforms:

1) 10-by-1000-mic.sec. waveform with a peak voltage of 1500 V and a peak current of 60 A.
2) 8-by-20-mic.sec. waveform with a peak voltage of 1000 V and a peak current of 500 A.

2. Power Conditioning:

a. Protect [**susceptible**]DDC system products connected to ac power circuits from irregularities and noise rejection. Characteristics of power-line conditioner shall be as follows:

1) At 85 percent load, output voltage shall not deviate by more than plus or minus 1 percent of nominal when input voltage fluctuates between minus 20 percent to plus 10 percent of nominal.
2) During load changes from zero to full load, output voltage shall not deviate by more than plus or minus 3 percent of nominal.
3) Accomplish full correction of load switching disturbances within five cycles, and 95 percent correction within two cycles of onset of disturbance.
4) Total harmonic distortion shall not exceed 3-1/2 percent at full load.

3. Ground Fault: Protect products from ground fault by providing suitable grounding. Products shall not fail due to ground fault condition.

2.5 SYSTEM ARCHITECTURE

A. System architecture shall consist of no more than two levels of LANs.

1. Level one LAN shall connect network controllers and operator workstations.
2. Level one LAN shall connect programmable application controllers to other programmable application controllers, and to network controllers.
3. Level two LAN shall connect application-specific controllers to programmable application controllers and network controllers.
4. Level two LAN shall connect application-specific controllers to application-specific controllers.

Coordinate requirements in "Minimum Data Transfer and Communication Speed" Paragraph below with "Networks" Article to ensure that speed requirements retained for a project can be achieved by networks retained for a project.

B. Minimum Data Transfer and Communication Speed:

In first subparagraph below, retain "100" or "10" option for Ethernet networks. Retain "2.5" option for ATA 878.1 networks. Retain "1.25" option for CEA-709.1-C networks.

1. LAN Connecting Operator Workstations and Network Controllers: 100 Mbps.
2. LAN Connecting Programmable Application Controllers: 1000 kbps.
3. LAN Connecting Application-Specific Controllers: 156,000 bps, (District preferred), or provide a sufficient data transfer rate required to keep the LAN Connecting Application-Specific Controllers from limiting the network speed.

C. DDC system shall consist of dedicated[**and separated**] LANs that are not shared with other building systems and tenant data and communication networks.

D. System architecture shall be modular and have inherent ability to expand to not less than two times system size indicated with no impact to performance indicated.

E. System architecture shall perform modifications without having to remove and replace existing network equipment.

F. Number of LANs and associated communication shall be transparent to operator. All I/O points residing on any LAN shall be capable of global sharing between all system LANs.

G. System design shall eliminate dependence on any single device for system alarm reporting and control execution. Each controller shall operate independently by performing its' own control, alarm management and historical data collection.

H. Special Network Architecture Requirements:

1. Air-Handling Systems: For control applications of an air-handling system that consists of air-handling unit(s) and VAV terminal units, include a dedicated LAN of application-specific controllers serving VAV terminal units connected directly to controller that is controlling air-handling system air-handling unit(s). Basically, create a DDC system LAN that aligns with air-handling system being controlled.
2. **<Insert additional requirements>**.

2.6 DDC SYSTEM OPERATOR INTERFACES

A. Operator Means of System Access: Operator shall be able to access entire DDC system through any of multiple means, including:

1. Desktop and portable operator workstation with hardwired connection through LAN port.
2. Portable operator terminal with hardwired connection through LAN port.
3. Portable operator workstation with wireless connection through LAN router.
4. Mobile device and application with secured wireless connection through LAN router or cellular data service.
5. Remote connection through Web access.
6. Any light duty device that is capable of web access.

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

C. Network Ports: For hardwired connection of desktop or portable operator workstation. Network port shall be easily accessible, properly protected, clearly labeled, and installed at the following locations:

Seven subparagraphs below are examples only.

1. Each mechanical equipment room.
2. Each boiler room.
3. Each chiller room or outdoor chiller yard.

4. Each cooling tower location.
5. Each different roof level with roof-mounted air-handling units or rooftop units.
6. Security system command center.
7. Fire-alarm system command center.

D. Desktop Operator Workstations:

1. Connect to DDC system Level one LAN through a communications port directly on LAN or through a communications port on a DDC controller.
2. Able to communicate with any device located on any DDC system LAN.

E. Portable Operator Workstations:

1. Connect to DDC system Level one LAN through a communications port directly on LAN or through a communications port on a DDC controller.
2. Able to communicate with any device located on any DDC system LAN.
3. Connect to DDC system Level two LAN through a communications port on an application-specific controller, or a room temperature sensor connected to an application-specific controller.
4. Connect to system through a wireless router connected to Level one LAN.
5. Connect to system through a cellular data service.
6. Portable operator workstation shall be able to communicate with any device connected to any system LAN regardless of point of physical connection to system.
7. Monitor, program, schedule, adjust set points, and report capabilities of I/O connected anywhere in system.
8. Have dynamic graphic displays that are identical to desktop operator workstations.

F. Mobile Device:

1. Connect to system through a wireless router connected to LAN and cellular data service.
2. Able to communicate with any DDC controller connected to DDC system using secure web access.

G. Critical Alarm Reporting:

1. Operator-selected critical alarms shall be sent by DDC system to notify operator of critical alarms that require immediate attention.
2. DDC system shall send alarm notification to multiple recipients that are assigned for each alarm.
3. DDC system shall notify recipients by any or all means, including e-mail, text message and prerecorded phone message to mobile and landline phone numbers.

H. Simultaneous Operator Use: Capable of accommodating up to 10 simultaneous operators that are accessing DDC system through any one of operator interfaces indicated.

2.7 NETWORKS

A. Acceptable networks for connecting operator workstations, mobile devices, and network controllers include the following:

Retain applicable subparagraphs below to suit DDC system size and complexity.

1. ATA 878.1, ARCNET.
2. BACnet IP.
3. IEEE 8802-3, Ethernet, (MS/TP).

B. Acceptable networks for connecting programmable application controllers include the following:

Retain applicable subparagraphs below to suit DDC system size and complexity.

1. ATA 878.1, ARCNET.
2. BACnet IP.
3. IEEE 8802-3, Ethernet, (MS/TP).
4. RS-485.
5. <**Insert type**>.

C. Acceptable networks for connecting application-specific controllers include the following:

Retain applicable subparagraphs below to suit DDC system size and complexity.

1. ATA 878.1, ARCNET.
2. CEA-709.1-C.
3. EIA-485A.
4. BACnet IP.
5. IEEE 8802-3, Ethernet, (MS/TP).
6. RS-485.

2.8 NETWORK COMMUNICATION PROTOCOL

A. Network communication protocol(s) used throughout entire DDC system shall be open to Owner and available to other companies for use in making future modifications to DDC system.

Retain "ASHRAE 135 Protocol" Paragraph below to limit entire DDC system communication protocol to ASHRAE 135.

B. ASHRAE 135 Protocol:

1. ASHRAE 135 communication protocol shall be sole and native protocol used throughout entire DDC system.

2. DDC system shall not require use of gateways except to integrate HVAC equipment and other building systems and equipment, not required to use ASHRAE 135 communication protocol.
3. If used, gateways shall connect to DDC system using ASHRAE 135 communication protocol and Project object properties and read/write services indicated by interoperability schedule.
4. Operator workstations, controllers and other network devices shall be tested and listed by BACnet Testing Laboratories.

2.9 DESKTOP OPERATOR WORKSTATIONS

If multiple desktop operator workstations having unique requirements are required, copy this article and re-edit for each operator workstation's requirements.

A. Description: A tower or all-in-one computer designed for normal use at a single, semipermanent location.

B. Performance Requirements:

1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
2. Energy Star compliant.

C. Personal Computer:

1. Minimum Processor Speed: **<Insert gigahertz>**.
2. RAM:

    a. Capacity: [**2**] [**4**] [**8**] <**Insert value**> [**GB**].
    b. Speed and Type: [**1333**] **<Insert value>** MHz, **<Insert type>**.

3. Hard Drive:

    a. Media: [**Solid state**] [**Rotating disc, nominal rotational speed of 7200 rpm**] [**Hybrid solid-state and rotating disc**].
    b. Number of Hard Drives: [**One**] [**Two**] **<Insert number>**.
    c. Capacity: **<Insert number and measurement unit>**.
    d. Minimum Average Seek Time: **<Insert number and measurement unit>**.
    e. Cache Buffer Size: **<Insert number and measurement unit>**.
    f. **<Insert requirements>**.

4. Second Hard Drive:

    a. Media: [**Solid state**] [**Rotating disc, nominal rotational speed of 7200 rpm**] [**Hybrid solid-state and rotating disc**].
    b. Capacity: **<Insert number and measurement unit>**.
    c. Minimum Average Seek Time: **<Insert number and measurement unit>**.

d. Cache Buffer Size: **<Insert number and measurement unit>**.
e. **<Insert requirements>**.

5. Optical Drive:

a. Type: **<Insert type>**.
b. Minimum Average Access Time: **<Insert number>** ms.
c. Data Transfer Speed: **<Insert number>** [**MB**] [**TB**]/s.
d. Reading Formats: Data, audio, recordable, **<Insert other>** and rewritable.

6. Optical Read and Write Drive:

a. Include with at least 2 MB of data buffer.
b. Type: **<Insert type>**.
c. Minimum Data Buffer Capacity: **<Insert number and measurement unit>**.
d. Minimum Average Access Time: **<Insert number>** ms.
e. Nominal Data Transfer Rates:

1) Reading: **<Insert number>** [**MB**] [**TB**]/s.
2) Writing: **<Insert number>** [**MB**] [**TB**]/s.

f. Average access time of 150 ms or less.
g. MTBF of at least 100,000 power-on hours.

7. At least four expansion slots of [**32**] [**64**] **<Insert number>** bit.
8. Video Card:

a. Resolution: [**1920 by 1200**] **<Insert values>** pixels.
b. RAM: **<Insert number>** [**MB**] [**GB**] [**TB**].
c. Controller Speed: **<Insert number>** [**MHz**] [**GHz**].
d. On-Board Memory Speed: **<Insert number>** [**MHz**] [**GHz**].
e. On-Board Memory Data Width: **<Insert number>** bit.

9. Sound Card:

a. At least 128 voice wavetable synthesis.
b. Capable of delivering three-dimensional sound effects.
c. High-resolution 16-bit stereo digital audio recording and playback with user-selectable sample rates up to 48,000 Hz.

10. Network Interface Card: Include card with connection, as applicable.

a. 10-100-1000 base TX Ethernet with RJ45 connector port.
b. 100 base FX Ethernet with SC or ST port.
c. Wireless Ethernet, 802.11 a/b/g/n.

11. I/O Ports:

a. Two USB 3.0 ports on front panel, six on back panel, and three internal on motherboard.
b. One serial port.
c. One parallel port.
d. Two PS/2 ports.
e. One RJ-45.
f. One stereo line-in and headphone line-out on back panel.
g. One microphone and headphone connector on front panel.
h. One IEEE 1394 on front and back panel with PCI-e card.
i. One ESATA port on back panel.

12. Battery: Life of at least three years to maintain system clock/calendar and ROM, as a minimum.

D. Keyboard:

1. 101 enhanced keyboard.
2. Full upper- and lowercase ASCII keyset, numeric keypad, dedicated cursor control keypad, and 12 programmable function keys.
3. Wireless operation within up to 72 inches in front of operator workstation.

E. Pointing Device:

1. Either a two- or three-button mouse.
2. Wireless operation within up to 72 inches in front of operator workstation.

F. Flat Panel Display Monitor:

Copy and re-edit "Display" Subparagraph below if requirements are different for multiple displays.

1. Display:

a. Color display with **<Insert inches>** diagonal viewable area.
b. Digital input signal.
c. Aspect Ratio: [**16 to 9**] **<Insert value>**.
d. Antiglare display.
e. Response Time: **<Insert number>** ms.
f. Dynamic Contrast Ratio: [**50000 to 1**] **<Insert ratio>**.
g. Brightness: [**250 cd/sq. m**] **<Insert value>**.
h. Tilt adjustable base.
i. Energy Star compliant.
j. Resolution: [**1920 by 1080**] **<Insert value>** pixels at 60 Hz with pixel size of [**0.277**] **<Insert number>** mm or smaller.
k. Number of Displays: [**One**] [**Two**] **<Insert number>**.

G. Speakers:

1. Two, with individual controls for volume, bass and treble.

2. Signal to Noise Ratio: At least 65 dB.
3. Power: At least 4 W per speaker/channel.
4. Magnetic shielding to prevent distortion on the video monitor.

H. I/O Cabling: Include applicable cabling to connect I/O devices.

2.10 PORTABLE OPERATOR WORKSTATIONS

If multiple portable operator workstations having unique requirements are required, copy this article and re-edit to specify requirements for each operator workstation.

A. Description: A self-contained computer designed to allow for normal use in different locations and conditions.

B. Performance Requirements:

1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
2. Energy Star compliant.
3. Hardware and software shall support local down-loading to DDC controllers.
4. Data transfer rate to DDC controller shall be at network speed.

C. Processor:

1. Minimum Processor Speed: **<Insert gigahertz>**.
2. RAM:

a. Capacity: **<Insert value>** [**GB**] [**TB**].
b. Speed and Type: **<Insert value>** MHz, **<Insert type>**.

Copy and re-edit "Hard Drive" Subparagraph below if requirements are different for multiple hard drives.

3. Hard Drive:

a. Number of Hard Drives: [**One**] [**Two**] **<Insert number>**.
b. Capacity: **<Insert number and measurement unit>**.
c. Minimum Average Seek Time: **<Insert number and measurement unit>**.
d. Cache Buffer Size: **<Insert number and measurement unit>**.
e. **<Insert requirements>**.

4. Video Card: **<Insert number and measurement unit>** of RAM.

D. Input and Output Ports:

1. Serial port.
2. Shared port for external keyboard or mouse.
3. Four USB 3.0 ports.
4. Ethernet port.

5. HDMI port.

E. Battery:

1. Capable of supporting operation of portable operator workstation for a minimum of [**8**] <**Insert number**> hours.
2. Battery life of at least three years.
3. Battery charge time of less than three hours.
4. Spare Battery(ies). [**One**] [**Two**].

F. Keyboard:

1. 85-key [**backlit**]keyboard.
2. Full upper- and lowercase ASCII keyset.

G. Integral Pointing Device: Touchpad with two buttons. Gesture enabled.

H. Display:

1. **<Insert inches>** diagonal or larger high-definition WLED color display.
2. Antiglare screen.
3. [**1920 by 1080**] **<Insert value>** pixel resolution.
4. Brightness: 300 nits.

I. Network Interface Card: Include card with connection, as application.

1. 10-100-1000 base TX Ethernet with RJ45 connector port.
2. 100 base FX Ethernet with SC or ST port.
3. Wireless: Internal with integrated antenna, capable of supporting 802.11 a/b/g/n.

J. Digital Video Disc Rewrite Recorder (DVD+/-RW):

1. Compatible with DVD disks and data, audio, recordable and rewritable compact disks.
2. Nominal Data Transfer Rates:

    a. Reading: **<Insert number>** [**MB**] [**TB**]/s.
    b. Writing: **<Insert number>** [**MB**] [**TB**]/s.

3. 160-ms access time.

K. Accessories:

1. Nylon carrying case.
2. Docking station.
3. Bluetooth module with 4.0 standard technologies.
4. Mobile broadband card.
5. Wireless optical mouse.
6. **<Insert value>** [**GB**] [**TB**] portable hard drive.

7. Light-sensitive Web cam and noise-cancelling digital array microphone.
8. Category 6a patch cable. Minimum cable length shall be <**Insert length**>.
9. HDMI cable. Minimum cable length shall be **<Insert length>**.

2.11 SERVERS

Retain this article for DDC systems with large data storage requirements.

A. Description

1. District provides server with the specified capacity at minimum to support software provided from control contractor.
2. Test system locally at Project site before installing on District Server.
3. Provide District with all system software.
4. Control software shall be capable of operating all systems by any specified manufacturer.
5. Provide system that is compatible with any specified manufacturer.

B. Manufacturers

1. Automated Logic Corporation.
2. Carrier I-Vu.
3. Distech Controls Inc.
4. Honeywell International, Inc.
5. Johnson Controls.
6. Trane, Inc.
7. Viconics Technologies, Inc..
8. Or Equal.

C. Performance Requirements:

1. Operating System: Windows Server 2012R2, Virtual server, (VM Virtual Machine) running on Microsoft HyperV virtualization technology.
2. Minimum Central Processing Units: [**4**]<**Insert Value**>.
3. RAM:

    a. Capacity: [**16**]<**Insert Value**> GB.

4. Hard-Drive Storage: One drive with [**100**]<**Insert Value**> GB storage.

D. Servers shall include the following:

1. Full-feature backup server (server and backup minimum requirement) provided by District.

    a. Configurations and data to be backed up by vender or exported to local drive for District backup.

2. Software licenses for all software required to access graphics, point displays, trends, configure trends, configure points and controllers, or to download programming into the controllers without recurring fees. Software shall reside on the District's server.
3. Cable installation between server(s) and network.

2.12 PRINTERS

A. Color Laser Printer:

1. [**1200 by 1200**] **<Insert value>** dots per inch resolution black and white, [**1200 by 1200**] **<Insert value>** dots per inch resolution black and white and color.
2. First sheet printed within 10 seconds.
3. **<Insert number>** page per minute rated print speed at best quality mode.
4. Print buffer with at least [**512**] **<Insert value>** MB of RAM, expandable to at least [**one**] **<Insert value>** GB.
5. Complies with Energy Star requirements.
6. Capable of handling letter- and legal-size paper and overhead transparencies.
7. Two paper trays; one tray with **<Insert number>** sheet capacity, and one tray with 500 **<Insert number>** sheet capacity.
8. Two-sided printing.
9. At least **<Insert number>** page toner/cartridge capacity.

2.13 SYSTEM SOFTWARE

A. System Software Minimum Requirements:

1. Include all software fees. There shall be no required ongoing software fees to operate or customize the controls system.
2. Real-time multitasking and multiuser 64-bit operating system that allows concurrent multiple operator workstations operating and concurrent execution of multiple real-time programs and custom program development.
3. Operating system shall be capable of operating Microsoft Windows applications.
4. Database management software shall manage all data on an integrated and non-redundant basis. Additions and deletions to database shall be without detriment to existing data. Include cross linkages so no data required by a program can be deleted by an operator until that data have been deleted from respective programs.
5. Network communications software shall manage and control multiple network communications to provide exchange of global information and execution of global programs.
6. Operator interface software shall include day-to-day operator transaction processing, alarm and report handling, operator privilege level and data segregation control, custom programming, and online data modification capability.
7. Scheduling software shall schedule centrally based time and event, temporary, and exception day programs.

8. Provide all required software on operator workstation(s). Verify software functions properly. 30 days after testing system locally at Project site, work together with District personnel to install all required software on District server.

B. Operator Interface Software:

1. Minimize operator training through use of English language prorating and English language point identification.
2. Minimize use of a typewriter-style keyboard through use of a pointing device similar to a mouse.
3. Operator sign-off shall be a manual operation or, if no keyboard or mouse activity takes place, an automatic sign-off.
4. Automatic sign-off period shall be programmable from one to 60 minutes in one-minute increments on a per operator basis.
5. Operator sign-on and sign-off activity shall be recorded and sent to printer.
6. Security Access:

    a. Operator access to DDC system shall be under password control.
    b. An alphanumeric password shall be field assignable to each operator.
    c. Operators shall be able to access DDC system by entry of proper password.
    d. Operator password shall be same regardless of which computer or other interface means is used.
    e. Additions or changes made to passwords shall be updated automatically.
    f. Each operator shall be assigned an access level to restrict access to data and functions the operator is cable of performing.
    g. Software shall have at least five access levels.
    h. Each menu item shall be assigned an access level so that a one-for-one correspondence between operator assigned access level(s) and menu item access level(s) is required to gain access to menu item.
    i. Display menu items to operator with those capable of access highlighted. Menu and operator access level assignments shall be online programmable and under password control.

7. Data Segregation:

    a. Include data segregation for control of specific data routed to a operator workstation, to an operator or to a specific output device, such as a printer.
    b. Include at least [**32**] **<Insert number>** segregation groups.
    c. Segregation groups shall be selectable such as "fire points," "fire points on second floor," "space temperature points," "HVAC points," and so on.
    d. Points shall be assignable to multiple segregation groups. Display and output of data to printer or monitor shall occur where there is a match of operator or peripheral segregation group assignment and point segregations.
    e. Alarms shall be displayed and printed at each peripheral to which segregation allows, but only those operators assigned to peripheral and having proper authorization level will be allowed to acknowledge alarms.

f. Operators and peripherals shall be assignable to multiple segregation groups and all assignments are to be online programmable and under password control.

8. Operators shall be able to perform commands including:

a. Start or stop selected equipment.
b. Adjust set points.
c. Add, modify, and delete time programming.
d. Enable and disable process execution.
e. Lock and unlock alarm reporting for each point.
f. Enable and disable totalization for each point.
g. Enable and disable trending for each point.
h. Override control loop set points.
i. Enter temporary override schedules.
j. Define holiday schedules.
k. Change time and date.
l. Enter and modify analog alarm limits.
m. Enter and modify analog warning limits.
n. View limits.
o. Enable and disable demand limiting.
p. Enable and disable duty cycle.
q. Display logic programming for each control sequence.
r. **<Insert requirements>**.

9. Reporting:

a. Generated automatically and manually.
b. Sent to displays, printers and disk files.
c. Types of Reporting:

1) General listing of points.
2) List points currently in alarm.
3) List of off-line points.
4) List points currently in override status.
5) List of disabled points.
6) List points currently locked out.
7) List of items defined in a "Follow-Up" file.
8) List weekly schedules.
9) List holiday programming.
10) List of limits and deadbands.

10. Summaries: For specific points, for a logical point group, for an operator selected group(s), or for entire system without restriction due to hardware configuration.

C. Graphic Interface Software:

1. Graphic interface software is of critical importance to District. See Part 1 Articles "Presubmittal Meeting" and "Action Submittals" for special requirements related to graphics.
2. Graphics, visual display, colors, data display, diagrams, floor plans, etc., shall be same as, and as a minimum must resemble, District standard graphics. Prior to submittal, request a sample of graphics from District to use as a guide line.
3. Include a full interactive graphical selection means of accessing and displaying system data to operator. Include at least five levels with the penetration path operator assignable (for example, site, building, floor, air-handling unit, and supply temperature loop). Native language descriptors assigned to menu items are to be operator defined and modifiable under password control.
4. Include a hierarchical-linked dynamic graphic operator interface for accessing and displaying system data and commanding and modifying equipment operation. Interface shall use a pointing device with pull-down or penetrating menus, color and animation to facilitate operator understanding of system.
5. Include at least 10 levels of graphic penetration with the hierarchy operator assignable.
6. Descriptors for graphics, points, alarms and such shall be modified through operator workstation under password control.
7. Graphic displays shall be online user definable and modifiable using the hardware and software provided.
8. Data to be displayed within a graphic shall be assignable regardless of physical hardware address, communication or point type.
9. Graphics are to be online programmable and under password control.
10. Points may be assignable to multiple graphics where necessary to facilitate operator understanding of system operation.
11. Graphics shall also contain software points.
12. Penetration within a graphic hierarchy shall display each graphic name as graphics are selected to facilitate operator understanding.
13. Back-trace feature shall permit operator to move upward in the hierarchy using a pointing device. Back trace shall show all previous penetration levels. Include operator with option of showing each graphic full screen size with back trace as horizontal header or by showing a "stack" of graphics, each with a back trace.
14. Display operator accessed data on the monitor.
15. Operator shall select further penetration using pointing device to click on a site, building, floor, area, equipment, and so on. Defined and linked graphic below that selection shall then be displayed.
16. Include operator with means to directly access graphics without going through penetration path.
17. Dynamic data shall be assignable to graphics.
18. Display points (physical and software) with dynamic data provided by DDC system with appropriate text descriptors, status or value, and engineering unit.
19. Use color, rotation, or other highly visible means, to denote status and alarm states. Color shall be variable for each class of points, as chosen by operator.
20. Points shall be dynamic with operator adjustable update rates on a per point basis from [**one**] **<Insert value>** second to over a [**minute**] **<Insert value>**.
21. For operators with appropriate privilege, points shall be commanded directly from display using pointing device.

a. For an analog command point such as set point, current conditions and limits shall be displayed and operator can position new set point using pointing device.
b. For a digital command point such as valve position, valve shall show its current state such as open or closed and operator could select alternative position using pointing device.
c. Keyboard equivalent shall be available for those operators with that preference.

22. Operator shall be able to split or resize viewing screen into quadrants to show one graphic on one quadrant of screen and other graphics or spreadsheet, bar chart, word processing, curve plot and other information on other quadrants on screen. This feature shall allow real-time monitoring of one part of system while displaying other parts of system or data to better facilitate overall system operation.
23. Help Features:

a. On-line context-sensitive help utility to facilitate operator training and understanding.
b. Bridge to further explanation of selected keywords. Document shall contain text and graphics to clarify system operation.

1) If help feature does not have ability to bridge on keywords for more information, a complete set of user manuals shall be provided in an indexed word-processing program, which shall run concurrently with operating system software.

c. Available for Every Menu Item:

1) Index items for each system menu item.

24. Graphic generation software shall allow operator to add, modify, or delete system graphic displays.

a. Include libraries of symbols depicting HVAC symbols such as fans, coils, filters, dampers, valves pumps, and electrical symbols[**similar to those indicated**].
b. Graphic development package shall use a pointing device in conjunction with a drawing program to allow operator to perform the following:

1) Define background screens.
2) Define connecting lines and curves.
3) Locate, orient and size descriptive text.
4) Define and display colors for all elements.
5) Establish correlation between symbols or text and associated system points or other displays.

D. Project-Specific Graphics: Graphics documentation including:

Subparagraphs below are examples only.

1. Site plan showing each building, and additional site elements, which are being controlled or monitored by DDC system.
2. Plan for each building floor, including interstitial floors, and each roof level of each building, showing the following:

    a. Room layouts with room identification and name.
    b. Locations and identification of all monitored and controlled HVAC equipment and other equipment being monitored and controlled by DDC system.
    c. Location and identification of each hardware point being controlled or monitored by DDC system.
    d. **<Insert requirements>**.

3. Control schematic for each of following, including a graphic system schematic representation[**, similar to that indicated on Drawings,**] with point identification, set point and dynamic value indication[**, sequence of operation**] [**and**] [**control logic diagram**].
4. Graphic display for each piece of equipment connected to DDC system through a data communications link. Include dynamic indication of all points associated with equipment.
5. DDC system network riser diagram that shows schematic layout for entire system including all networks and all controllers, [**gateways**] [**operator workstations**] [**and**] [**other network devices**].

E. Customizing Software:

1. Software to modify and tailor DDC system to specific and unique requirements of equipment installed, to programs implemented and to staffing and operational practices planned. Provide all required software on operator workstation(s). Verify software functions properly. 30 days after testing system locally at Project site, work together with District personnel to install all required software on District server.
2. Online modification of DDC system configuration, program parameters, and database using menu selection and keyboard entry of data into preformatted display templates.
3. As a minimum, include the following modification capability:

    a. Operator assignment shall include designation of operator passwords, access levels, point segregation and auto sign-off.
    b. Peripheral assignment capability shall include assignment of segregation groups and operators to consoles and printers, designation of backup operator workstations and printers, designation of operator workstation header points and enabling and disabling of print-out of operator changes.
    c. System configuration and diagnostic capability shall include communications and peripheral port assignments, DDC controller assignments to network, DDC controller enable and disable, assignment of

command trace to points and application programs and initiation of diagnostics.

d. System text addition and change capability shall include English or native language descriptors for points, segregation groups and access levels and action messages for alarms, run time and trouble condition.

e. Time and schedule change capability shall include time and date set, time and occupancy schedules, exception and holiday schedules and daylight savings time schedules.

f. Point related change capability shall include the following:

1) System and point enable and disable.
2) Run-time enable and disable.
3) Assignment of points to segregation groups, calibration tables, lockout, and run time and to a fixed I/O value.
4) Assignment of alarm and warning limits.

g. Application program change capability shall include the following:

1) Enable and disable of software programs.
2) Programming changes.
3) Assignment of comfort limits, global points, time and event initiators, time and event schedules and enable and disable time and event programs.

4. Software shall allow operator to add points, or groups of points, to DDC system and to link them to energy optimization and management programs. Additions and modifications shall be online programmable using operator workstation, downloaded to other network devices and entered into their databases. After verification of point additions and associated program operation, database shall be uploaded and recorded on hard drive and disk for archived record.
5. Include high-level language programming software capability for implementation of custom DDC programs. Software shall include a compiler, linker, debugger, and up- and down-load capability. Include the graphical function block programming language support.
6. Include a library of DDC algorithms, intrinsic control operators, arithmetic, logic and relational operators for implementation of control sequences. Also include, as a minimum, the following:

a. Proportional control (P).
b. Proportional plus integral (PI).
c. Proportional plus integral plus derivative (PID).
d. Adaptive and intelligent self-learning control.

1) Algorithm shall monitor loop response to output corrections and adjust loop response characteristics according to time constant changes imposed.
2) Algorithm shall operate in a continuous self-learning manner and shall retain in memory a stored record of system dynamics so that on

system shut down and restart, learning process starts from where it left off.

7. Fully implemented intrinsic control operators including sequence, reversing, ratio, time delay, time of day, highest select AO, lowest select AO, analog controlled digital output, analog control AO, and digitally controlled AO.
8. Logic operators such as "And," "Or," "Not," and others that are part of a standard set available with a high-level language.
9. Arithmetic operators such as "Add," "Subtract," "Multiply," "Divide," and others that are part of a standard set available with a high-level language.
10. Relational operators such as "Equal To," "Not Equal To," "Less Than," "Greater Than," and others that are part of a standard set available with a high-level language.

F. Alarm Handling Software:

1. Include alarm handling software to report all alarm conditions monitored and transmitted through DDC controllers[**, gateways**] [**and other network devices**]. Provide all required software on operator workstation(s). Verify software functions properly. 30 days after testing system locally at Project site, work together with District personnel to install all required software on District server.
2. Include first in, first out handling of alarms according to alarm priority ranking, with most critical alarms first, and with buffer storage in case of simultaneous and multiple alarms.
3. Alarm handling shall be active at all times to ensure that alarms are processed even if an operator is not currently signed on to DDC system.
4. Alarms display shall include the following:

    a. Indication of alarm condition such as "Abnormal Off," "Hi Alarm," and "Low Alarm."
    b. "Analog Value" or "Status" group and point identification with native language point descriptor such as "Space Temperature, Building 110, 2nd Floor, Room 212."
    c. Discrete per point alarm action message, such as "Call Maintenance Dept. Ext-5561."
    d. Include extended message capability to allow assignment and printing of extended action messages. Capability shall be operator programmable and assignable on a per point basis.

5. Alarms shall be directed to appropriate operator workstations, printers, and individual operators by privilege level and segregation assignments.
6. Send e-mail alarm messages to designated operators.
7. Send e-mail, page, text and voice messages to designated operators for critical alarms.
8. Alarms shall be categorized and processed by class.

    a. Class 1:

1) Associated with fire, security and other extremely critical equipment monitoring functions; have alarm, trouble, return to normal, and acknowledge conditions printed and displayed.
2) Unacknowledged alarms to be placed in unacknowledged alarm buffer.
3) All conditions shall cause an audible sound and shall require individual acknowledgment to silence audible sound.

b. Class 2:

1) Critical, but not life-safety related, and processed same as Class 1 alarms, except do not require individual acknowledgment.
2) Acknowledgement may be through a multiple alarm acknowledgment.

c. Class 3:

1) General alarms; printed, displayed and placed in unacknowledged alarm buffer queues.
2) Each new alarm received shall cause an audible sound. Audible sound shall be silenced by "acknowledging" alarm or by pressing a "silence" key.
3) Acknowledgement of queued alarms shall be either on an individual basis or through a multiple alarm acknowledgement.
4) Alarms returning to normal condition shall be printed and not cause an audible sound or require acknowledgment.

d. Class 4:

1) Routine maintenance or other types of warning alarms.
2) Alarms to be printed only, with no display, no audible sound and no acknowledgment required.

9. Include an unacknowledged alarm indicator on display to alert operator that there are unacknowledged alarms in system. Operator shall be able to acknowledge alarms on an individual basis or through a multiple alarm acknowledge key, depending on alarm class.
10. To ensure that no alarm records are lost, it shall be possible to assign a backup printer to accept alarms in case of failure of primary printer.

G. Reports and Logs:

1. Include reporting software package that allows operator to select, modify, or create reports using DDC system I/O point data available. Provide all required software on operator workstation(s). Verify software functions properly. 30 days after testing system locally at Project site, work together with District personnel to install all required software on District server.
2. Each report shall be definable as to data content, format, interval and date.

3. Report data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on server for historical reporting.
4. Operator shall be able to obtain real-time logs of all I/O points by type or status, such as alarm, point lockout, logging on and off a operator workstation, changing a point value, modifying a program, enabling/disabling an object, viewing a graphic display, or normal.
5. Reports and logs shall be stored on [**operator workstation**] [**and**] [**server**] hard drives in a format that is readily accessible by other standard software applications, including spreadsheets and word processing.
6. Reports and logs shall be readily printed and set to be printed either on operator command or at a specific time each day.

H. Standard Reports: Standard DDC system reports shall be provided and operator shall be able to customize reports later.

1. All I/O: With current status and values.
2. All Operator Changes. Examples include setpoint changes, time schedule overrides, alarm limits, etc.
3. Alarm: All current alarms, except those in alarm lockout.
4. Disabled I/O: All I/O points that are disabled.
5. Alarm Lockout I/O: All I/O points in alarm lockout, whether manual or automatic.
6. Alarm Lockout I/O in Alarm: All I/O in alarm lockout that are currently in alarm.
7. Logs:

    a. Alarm history.
    b. System messages.
    c. System events.
    d. Trends.

I. Custom Reports: Operator shall be able to easily define any system data into a daily, weekly, monthly, or annual report. Reports shall be time and date stamped and shall contain a report title.

Retain "HVAC Equipment Reports" Paragraph below to require Project-specific HVAC equipment reports to be prepared by a DDC system installer.

J. HVAC Equipment Reports: Prepare Project-specific reports.

1. Chiller Report: Daily report showing operating conditions of each chiller according to ASHRAE 147, including:

Revise subparagraphs below to suit Project. Include DDC system with instruments required to provide information indicated.

    a. Chilled-water entering temperature.
    b. Chilled-water leaving temperature.
    c. Chilled-water flow rate.
    d. Chilled-water inlet and outlet pressures.
    e. Evaporator refrigerant pressure and temperature.

f. Condenser refrigerant pressure and liquid temperature.
g. Condenser-water entering temperature.
h. Condenser-water leaving temperature.
i. Condenser-water flow rate.
j. Refrigerant levels.
k. Oil pressure and temperature.
l. Oil level.
m. Compressor refrigerant discharge temperature.
n. Compressor refrigerant suction temperature.
o. Addition of refrigerant.
p. Addition of oil.
q. Vibration levels or observation that vibration is not excessive.
r. Motor amperes per phase.
s. Motor volts per phase.
t. Refrigerant monitor level (PPM).
u. Purge exhaust time or discharge count.
v. Ambient temperature (dry bulb and wet bulb).
w. Date and time logged.

2.14 ASHRAE 135 GATEWAYS

Gateways require a thorough understanding of their application. Use caution when connecting non-BACnet to BACnet protocol. Research gateway manufacturers for price, options, and performance. Design for each gateway should include an interoperability schedule showing each point or event on non-BACnet side that BACnet "client" will read, and each parameter that BACnet network will write to for BACnet services, or BACnet BIBBs, defined in ASHRAE 135, Annex K.

A. Include BACnet communication ports, whenever available as an equipment OEM standard option, for integration via a single communication cable. BACnet-controlled plant equipment includes boilers, chillers, **<Insert equipment,>** and variable-speed drives.

B. Include gateways to connect BACnet to legacy systems, existing non-BACnet devices, and existing non-BACnet DDC-controlled equipment, only when specifically requested and approved by District.

C. Include with each gateway an interoperability schedule showing each point or event on legacy side that BACnet "client" will read, and each parameter that BACnet network will write to. Describe this interoperability of BACnet services, or BIBBs, defined in ASHRAE 135, Annex K.

D. Gateway Minimum Requirements:

1. Read and view all readable object properties on non-BACnet network to BACnet network and vice versa where applicable.
2. Write to all writeable object properties on non-BACnet network from BACnet network and vice versa where applicable.

3. Include single-pass (only one protocol to BACnet without intermediary protocols) translation from non-BACnet protocol to BACnet and vice versa.
4. Comply with requirements of Data Sharing Read Property, Data Sharing Write Property, Device Management Dynamic Device Binding-B, and Device Management Communication Control BIBBs according to ASHRAE 135.
5. Hardware, software, software licenses, and configuration tools for operator-to-gateway communications. Provide all required software on operator workstation(s). Verify software functions properly. 30 days after testing system locally at Project site, work together with District personnel to install all required software on District server.
6. Backup programming and parameters on CD media and the ability to modify, download, backup, and restore gateway configuration.

2.15 ASHRAE 135 PROTOCOL ANALYZER

Retain protocol analyzer after consulting District and confirming operators require it, as it takes a moderate level of skill and knowledge to use.

Protocol analyzer is typically software for connecting a computer to any ASHRAE 135 network for use in gathering basic system information. It is most useful for integration projects with poorly documented systems and where different DDC system manufacturers' products reside on same network.

A. Analyzer and required cables and fittings for connection to ASHRAE 135 network.

B. Analyzer shall include the following minimum capabilities:

1. Capture and store to a file data traffic on all network levels.
2. Measure bandwidth usage.
3. Filtering options with ability to ignore select traffic.

2.16 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.
3. Controllers located outdoors shall be rated for operation at 40 to 150 deg F.

F. Power and Noise Immunity:

1. Controller shall operate at 90 to 110 percent of nominal voltage rating and shall perform an orderly shutdown below 80 percent of nominal voltage.
2. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios with up to 5 W of power located within 36 inches of enclosure.

Retain "DDC Controller Spare I/O Point Capacity" Paragraph below to require spare point capacity for future growth.

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

1. Network Controllers:

a. [**10**] [**20**] **<Insert number>** percent of each AI, AO, BI, and BO point connected to controller.
b. Minimum Spare I/O Points per Controller:

1) AIs: [**Two**] [**Three**] **<Insert number>**.
2) AOs: [**Two**] [**Three**] **<Insert number>**.
3) BIs: [**Three**] [**Five**] **<Insert number>**.
4) BOs: [**Three**] [**Five**] **<Insert number>**.

2. Programmable Application Controllers:

a. [**10**] [**20**] **<Insert number>** percent of each AI, AO, BI, and BO point connected to controller.
b. Minimum Spare I/O Points per Controller:

1) AIs: [**Two**] [**Three**] **<Insert number>**.
2) AOs: [**Two**] [**Three**] **<Insert number>**.
3) BIs: [**Three**] [**Five**] **<Insert number>**.
4) BOs: [**Three**] [**Five**] **<Insert number>**.

3. Application-Specific Controllers:

a. [**10**] **<Insert number>** percent of each AI, AO, BI, and BO point connected to controller.
b. Minimum Spare I/O Points per Controller:

1) AIs: [**One**] [**Two**] **<Insert number>**.
2) AOs: [**One**] [**Two**] **<Insert number>**.
3) BIs: [**One**] [**Two**] **<Insert number>**.

4) BOs: [**One**] [**Two**] **<Insert number>**.

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.

I. Input and Output Point Interface:

1. Hardwired input and output points shall connect to network, programmable application and application-specific controllers.
2. Input and output points shall be protected so shorting of point to itself, to another point, or to ground will not damage controller.
3. Input and output points shall be protected from voltage up to 24 V of any duration so that contact will not damage controller.
4. AIs:

    a. AIs shall include monitoring of low-voltage (zero- to 10-V dc), current (4 to 20 mA) and resistance signals from thermistor and RTD sensors.
    b. AIs shall be compatible with, and field configurable to, sensor and transmitters installed.
    c. Controller AIs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of [**8**] [**12**] **<Insert value>** bits or better to comply with accuracy requirements indicated.
    d. Signal conditioning including transient rejection shall be provided for each AI.
    e. Capable of being individually calibrated for zero and span.
    f. Incorporate common-mode noise rejection of at least 50 dB from zero to 100 Hz for differential inputs, and normal-mode noise rejection of at least 20 dB at 60 Hz from a source impedance of 10000 ohms.

5. AOs:

    a. Controller AOs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of [**8**] [**12**] **<Insert value>** bits or better to comply with accuracy requirements indicated.
    b. Output signals shall have a range of [**4 to 20 mA dc**] [**or**] [**zero- to 10-V dc**] as required to include proper control of output device.
    c. Capable of being individually calibrated for zero and span.
    d. AOs shall not exhibit a drift of greater than 0.4 percent of range per year.

6. BIs:

a. Controller BIs shall accept contact closures and shall ignore transients of less than 5-ms duration.
b. Isolation and protection against an applied steady-state voltage of up to 180-V ac peak.
c. BIs shall include a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against effects of contact bounce and noise.
d. BIs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.
e. Pulse accumulation input points shall comply with all requirements of BIs and accept up to 10 pulses per second for pulse accumulation. Buffer shall be provided to totalize pulses. Pulse accumulator shall accept rates of at least 20 pulses per second. The totalized value shall be reset to zero on operator's command.

7. BOs:

a. Controller BOs shall include relay contact closures or triac outputs for momentary and maintained operation of output devices.

1) Relay contact closures shall have a minimum duration of 0.1 second. Relays shall include at least 180 V of isolation. Electromagnetic interference suppression shall be provided on all output lines to limit transients to non-damaging levels. Minimum contact rating shall be 1 A at 24-V ac.
2) Triac outputs shall include at least 180 V of isolation. Minimum contact rating shall be 1 A at 24-V ac.

b. BOs shall include for two-state operation or a pulsed low-voltage signal for pulse-width modulation control.
c. BOs shall be selectable for either normally open or normally closed operation.
d. Include tristate outputs (two coordinated BOs) for control of three-point floating-type electronic actuators without feedback.
e. Limit use of three-point floating devices to VAV terminal unit control applications, [**and other applications indicated on Drawings,**] **<Insert applications>**. Control algorithms shall operate actuator to one end of its stroke once every [**12**] [**24**] **<Insert time>** hours for verification of operator tracking.

2.17 NETWORK CONTROLLERS

A. General Network Controller Requirements:

1. Include adequate number of controllers to achieve performance indicated.
2. System shall consist of one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.

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

B. Communication:

1. Network controllers shall communicate with other devices on DDC system [**Level one**] **<Insert level>** network.
2. Network controller also shall perform routing if connected to a network of programmable application and application-specific controllers.

C. Operator Interface:

1. Controller shall be equipped with a service communications port for connection to a portable operator workstation[**or mobile device**].

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. For additional requirements, see Part 3 Article “Control Devices for Equipment Manufacturer Factory Installation/Coordination”.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

2.18 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 workstation[**or mobile device**].

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. For additional requirements, refer to Part 3 Article “Control Devices for Equipment Manufacturer Factory Installation/Coordination”.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

2.19 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 normal 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 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.
4. For additional requirements, refer to Part 3 Article “Control Devices for Equipment Manufacturer Factory Installation/Coordination”.

2.20 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**] **<Insert number>**-character point name and up to [**16**] **<Insert number>**-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.
e. Include independent scheduling ability for each piece of equipment.

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.

H. Remote Communication:

1. System shall have ability to dial out in the event of an alarm.

I. Sequencing: Include application software based on sequences of operation indicated to properly sequence chillers, boilers, and other applicable HVAC equipment.

J. Control Loops:

1. Support any of the following control loops, as applicable to control required:

a. Two-position (on/off, open/close, slow/fast) control.
b. Proportional control.
c. Proportional plus integral (PI) control.
d. Proportional plus integral plus derivative (PID) control.

1) Include PID algorithms with direct or reverse action and anti-windup.
2) Algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs.
3) Controlled variable, set point, and PID gains shall be operator-selectable.

e. Adaptive (automatic tuning).

K. Staggered Start: Application shall prevent all controlled equipment from simultaneously restarting after a power outage. Order which equipment (or groups of equipment) is started, along with the time delay between starts, shall be operator-selectable.

L. Anti-Short Cycling:

1. BO points shall be protected from short cycling.
2. Feature shall allow minimum on-time and off-time to be selected.

M. On and Off Control with Differential:

1. Include an algorithm that allows a BO to be cycled based on a controlled variable and set point.
2. Algorithm shall be direct- or reverse-acting and incorporate an adjustable differential.

N. Run-Time Totalization:

1. Include software to totalize run-times for all BI [**and BO**]points.
2. A high run-time alarm shall be assigned, if required, by operator.

2.21 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.

Retain any of first two subparagraphs below to restrict enclosure size.

4. Individual wall-mounted single-door enclosures shall not exceed [**36 inches**] **<Insert dimension>** wide and [**48 inches**] [**60 inches**] **<Insert dimension>** high.
5. Individual wall-mounted double-door enclosures shall not exceed [**60 inches**] **<Insert dimension>** wide and [**36 inches**] **<Insert dimension>** high.

B. Internal Arrangement:

1. Internal layout of enclosure shall group and protect pneumatic, electric, and electronic components associated with a controller, but not an integral part of controller.
2. Arrange layout to group similar products together.
3. Include a barrier between line-voltage and low-voltage electrical and electronic products.
4. Factory or shop install products, tubing, cabling and wiring complying with requirements and standards indicated.
5. Terminate field cable and wire using heavy-duty terminal blocks.
6. Include spare terminals, equal to not less than [**10**] [**20**] **<Insert number>** percent of used terminals.
7. Include spade lugs for stranded cable and wire.
8. Install a maximum of two wires on each side of a terminal.
9. Include enclosure field power supply with a toggle-type switch located at entrance inside enclosure to disconnect power.

Retain first subparagraph below for enclosure-mounted receptacle.

10. Include enclosure with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with a 5-A circuit breaker.
11. Mount products within enclosure on removable internal panel(s).
12. Include products mounted in enclosures with engraved, laminated phenolic nameplates (black letters on a white background). The nameplates shall have at least 1/4-inch-high lettering.
13. Route tubing cable and wire located inside enclosure within a raceway with a continuous removable cover.
14. Label each end of cable, wire and tubing in enclosure following an approved identification system that extends from field I/O connection and all intermediate connections throughout length to controller connection.
15. Size enclosure internal panel to include at least [**25**] **<Insert number>** percent spare area on face of panel.

C. Environmental Requirements:

1. Evaluate temperature and humidity requirements of each product to be installed within each enclosure.
2. Calculate enclosure internal operating temperature considering heat dissipation of all products installed within enclosure and ambient effects (solar, conduction and wind) on enclosure.

3. Where required by application, include temperature-controlled electrical heat to maintain inside of enclosure above minimum operating temperature of product with most stringent requirement.
4. Where required by application, include temperature-controlled ventilation fans with filtered louver(s) to maintain inside of enclosure below maximum operating temperature of product with most stringent requirement.
5. Include temperature-controlled cooling within the enclosure for applications where ventilation fans cannot maintain inside temperature of enclosure below maximum operating temperature of product with most stringent requirement.
6. Where required by application, include humidity-controlled electric dehumidifier or cooling to maintain inside of enclosure below maximum relative humidity of product with most stringent requirement and to prevent surface condensation within enclosure.

D. Wall-Mounted, NEMA 250, Type 1:

1. Enclosure shall be NRTL listed according to UL 50 or UL 50E.
2. Construct enclosure of steel, not less than:

    a. Enclosure size less than 24 in.: [**0.053 in.**] [**or**] [**0.067 in.**] thick.
    b. Enclosure size 24 in. and larger: [**0.067 in.**] [**or**] [**0.093 in.**] thick.

3. Finish enclosure inside and out with polyester powder coating that is electrostatically applied and then baked to bond to substrate.

    a. Exterior color shall be [**white**] [**ANSI 61 gray**] [**selected by Architect**] [**manufacturer's standard**] **<Insert color>**.
    b. Interior color shall be [**white**] [**ANSI 61 gray**] [**manufacturer's standard**].

4. Hinged door full size of front face of enclosure and supported using:

    a. Enclosures sizes less than 36 in. tall: Multiple butt hinges.
    b. Enclosures sizes 36 in. tall and larger: Continuous piano hinges.

5. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.

    a. Size less than 24 in.: [**Solid**] [**or**] [**Perforated**] steel, 0.053 in. thick.
    b. Size 24 in. and larger: Solid [**aluminum, 0.10 in.**] [**or**] [**steel, 0.093 in.**] thick.

6. Internal panel mounting hardware, grounding hardware and sealing washers.
7. Grounding stud on enclosure body.
8. Thermoplastic pocket on inside of door for record Drawings and Product Data.

E. Wall Mounted NEMA 250, Types 4 and 12:

1. Enclosure shall be NRTL listed according to UL 508A.
2. Seam and joints are continuously welded and ground smooth.

3. Where recessed enclosures are indicated, include enclosures with face flange for flush mounting.
4. Externally formed body flange around perimeter of enclosure face for continuous perimeter seamless gasket door seal.
5. Single-door enclosure sizes up to 60 inches tall by 36 inches wide.
6. Double-door enclosure sizes up to 36 inches tall by 60 inches wide.
7. Construct enclosure of steel, not less than the following:

    a. Size Less Than 24 Inches: [**0.053 inch**] [**or**] [**0.067 inch**] thick.
    b. Size 24 Inches and Larger: 0.067 inch thick.

8. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.

    a. Exterior color shall be [**white**] [**ANSI 61 gray**] [**as selected by Architect**] [**manufacturer's standard**] **<Insert color>**.
    b. Interior color shall be [**white**] [**ANSI 61 gray**] [**manufacturer's standard**].

9. Corner-formed door, full size of enclosure face, supported using multiple concealed hinges with easily removable hinge pins.

    a. Sizes through 24 Inches Tall: Two hinges.
    b. Sizes between 24 Inches through 48 Inches Tall: Three hinges.
    c. Sizes Larger 48 Inches Tall: Four hinges.

10. Double-door enclosures with overlapping door design to include unobstructed full-width access.

    a. Single-door enclosures 48 inches and taller, and all double-door enclosures, with three-point (top, middle and bottom) latch system.

11. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.

    a. Size Less Than 24 Inches: [**Solid**] [**or**] [**perforated**] steel, 0.053 inch thick.
    b. Size 24 Inches and Larger: Solid [**aluminum, 0.10 inch**] [**or**] [**steel, 0.093 inch**] thick.

12. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.
13. Grounding stud on enclosure body.
14. Thermoplastic pocket on inside of door for record Drawings and Product Data.

F. Accessories:

1. Ventilation Fans, Filtered Intake and Exhaust Grilles:

    a. Number and size of fans, filters and grilles as required by application.

b. Compact cooling fans engineered for 50,000 hours of continuous operation without lubrication or service.
c. Fans capable of being installed on any surface and in any position within enclosure for spot cooling or air circulation.
d. Thermostatic control with adjustable set point from 32 to 140 deg F.
e. Airflow Capacity at Zero Pressure:

1) 4-Inch Fan: 100 cfm.
2) 6-Inch Fan: 240 cfm.
3) 10-Inch Fan: 560 cfm.

f. Maximum operating temperature of 158 deg F.
g. 4-inch fan thermally protected and provided with permanently lubricated ball-bearings.
h. 6- and 10-inch fans with ball-bearing construction and split capacitor motors thermally protected to avoid premature failure.
i. Dynamically balanced impellers molded from polycarbonate material.
j. Fan furnished with power cord and polarized plug for power connection.
k. Fan brackets, finger guards and mounting hardware provided with fans to complete installation.
l. Removable Intake and Exhaust Grilles: [**ABS plastic**] [**or**] [**stainless steel**] of size to match fan size and suitable for NEMA 250, Types 1 and 12 enclosures.
m. Filters for NEMA 250, Type 1 Enclosures: Washable [**foam**] [**or**] [**aluminum**], of a size to match intake grille.
n. Filters for NEMA 250, Type 12 Enclosures: Disposable, of a size to match intake grille.

2.22 RELAYS

A. General-Purpose Relays:

1. Relays shall be heavy duty and rated for at least 10 A at 250-V ac and 60 Hz.
2. Relays shall be either double pole double throw (DPDT) or three-pole double throw, depending on the control application.
3. Use a plug-in-style relay with an eight-pin octal plug for DPDT relays and an 11-pin octal plug for three-pole double-throw relays.
4. Construct the contacts of either silver cadmium oxide or gold.
5. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
6. Relays shall have LED indication and a manual reset and push-to-test button.
7. Performance:

a. Mechanical Life: At least 10 million cycles.
b. Electrical Life: At least 100,000 cycles at rated load.
c. Pickup Time: 15 ms or less.
d. Dropout Time: 10 ms or less.
e. Pull-in Voltage: 85 percent of rated voltage.
f. Dropout Voltage: 50 percent of nominal rated voltage.

g. Power Consumption: 2 VA.
h. Ambient Operating Temperatures: Minus 40 to 115 deg F.

8. Equip relays with coil transient suppression to limit transients to non-damaging levels.
9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

B. Multifunction Time-Delay Relays:

1. Relays shall be continuous duty and rated for at least 10 A at 240-V ac and 60 Hz.
2. Relays shall be DPDT relay with up to eight programmable functions to provide on/off delay, interval and recycle timing functions.
3. Use a plug-in-style relay with either an 8- or 11-pin octal plug.
4. Construct the contacts of either silver cadmium oxide or gold.
5. Enclose the relay in a dust-tight cover.
6. Include knob and dial scale for setting delay time.
7. Performance:

a. Mechanical Life: At least 10 million cycles.
b. Electrical Life: At least 100,000 cycles at rated load.
c. Timing Ranges: Multiple ranges from 0.1 seconds to 100 minutes.
d. Repeatability: Within 2 percent.
e. Recycle Time: 45 ms.
f. Minimum Pulse Width Control: 50 ms.
g. Power Consumption: 5 VA or less at 120-V ac.
h. Ambient Operating Temperatures: Minus 40 to 115 deg F.

8. Equip relays with coil transient suppression to limit transients to non-damaging levels.
9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

C. Latching Relays:

1. Relays shall be continuous duty and rated for at least 10 A at 250-V ac and 60 Hz.
2. Relays shall be either DPDT or three-pole double throw, depending on the control application.
3. Use a plug-in-style relay with a multibladed plug.
4. Construct the contacts of either silver cadmium oxide or gold.
5. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
6. Performance:

a. Mechanical Life: At least 10 million cycles.
b. Electrical Life: At least 100,000 cycles at rated load.
c. Pickup Time: 15 ms or less.
d. Dropout Time: 10 ms or less.
e. Pull-in Voltage: 85 percent of rated voltage.
f. Dropout Voltage: 50 percent of nominal rated voltage.
g. Power Consumption: 2 VA.
h. Ambient Operating Temperatures: Minus 40 to 115 deg F.

7. Equip relays with coil transient suppression to limit transients to non-damaging levels.
8. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
9. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

D. Current Sensing Relay:

1. Monitors ac current.
2. Independent adjustable controls for pickup and dropout current.
3. Energized when supply voltage is present and current is above pickup setting.
4. De-energizes when monitored current is below dropout current.
5. Dropout current is adjustable from 50 to 95 percent of pickup current.
6. Include a current transformer, if required for application.
7. House current sensing relay and current transformer in its own enclosure. Use NEMA 250, Type 12 enclosure for indoors and NEMA 250, Type 4 for outdoors.

E. Combination On-Off Status Sensor and On-Off Relay:

1. Description:

a. On-off control and status indication in a single device.
b. LED status indication of activated relay and current trigger.
c. Closed-Open-Auto override switch located on the load side of the relay.

2. Performance:

a. Ambient Temperature: Minus 30 to 140 deg F.
b. Voltage Rating: Single-phase loads rated for 300-V ac. Three-phase loads rated for 600-V ac.

3. Status Indication:

a. Current Sensor: Integral sensing for single-phase loads up to 20 A and external solid or split sensing ring for three-phase loads up to 150 A.
b. Current Sensor Range: As required by application.
c. Current Set Point: [**Fixed**] [**Adjustable**] [**Fixed or adjustable as required by application**].
d. Current Sensor Output:

Retain any of first four subparagraphs below as applicable to Project.

1) Solid-state, single-pole double-throw contact rated for 30-V ac and dc and for 0.4 A.
2) Solid-state, single-pole double-throw contact rated for 120-V ac and 1.0 A.
3) Analog, zero- to 5- or 10-V dc.
4) Analog, 4 to 20 mA, loop powered.

4. Relay: Single-pole double-throw, continuous-duty coil; rated for 10-million mechanical cycles.

2.23 ELECTRICAL POWER DEVICES

A. Transformers:

1. Transformer shall be sized for the total connected load, plus an additional 25 percent of connected load.
2. Transformer shall be at least [**40**] [**100**] **<Insert value>** VA.
3. Transformer shall have both primary and secondary fuses.

2.24 CONTROL WIRE AND CABLE

A. Wire: Single conductor control wiring above 24 V.

1. Wire size shall be at least[**No. 18**] [**No. 16**] [**No. 14**] **<Insert value>** AWG.
2. Conductor shall be 7/24 soft annealed copper strand with 2- to 2.5-inch lay.
3. Conductor insulation shall be 600 V, Type THWN or Type THHN, and 90 deg C according to UL 83.
4. Conductor colors shall be black (hot), white (neutral), and green (ground).
5. Furnish green wire on spools.

B. Single Twisted Shielded Instrumentation Cable above 24 V:

1. Wire size shall be a minimum [**No. 18**] [**No. 20**] [**No. 22**] **<Insert value>** 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.

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

1. Wire size shall be a minimum [**No. 18**] [**No. 20**] [**No. 22**] **<Insert value>** 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.

D. LAN and Communication Cable: Comply with DDC system manufacturer requirements for network being installed.

1. Cable shall be balanced twisted pair.
2. Comply with requirements for balanced twisted pair cable described in [**Section 26 05 23 "Control-Voltage Electrical Power Cables"**] [**Section 27 15 13 "Communications Copper Horizontal Cabling"**] and the following:
3. Cable shall be plenum rated.
4. Cable shall have a unique color that is different from other cables used on Project.

2.25 RACEWAYS

A. Comply with requirements in Section 26 05 33 "Raceways and Boxes for Electrical Systems" for electrical power raceways and boxes.

B. Comply with requirements in Section 27 05 28 "Pathways for Communications Systems" for raceways for balanced twisted pair cables and optical fiber cables.

2.26 OPTICAL FIBER CABLE AND CONNECTORS

A. Comply with requirements in Section 27 13 23 "Communications Optical Fiber Backbone Cabling" for optical fiber backbone cabling and connectors.

B. Comply with requirements in Section 27 15 23 "Communications Optical Fiber Horizontal Cabling" for optical fiber horizontal cabling and connectors.

2.27 CONTROL POWER WIRING AND RACEWAYS

A. Comply with requirements in Section 26 05 19 "Low-Voltage Electrical Power Conductors and Cables" electrical power conductors and cables.

B. Comply with requirements in Section 26 05 33 "Raceways and Boxes for Electrical Systems" for electrical power raceways and boxes.

2.28 ACCESSORIES

A. Pressure Electric Switches:

1. Diaphragm-operated snap acting switch.
2. Set point adjustable from 3 to 20 psig.
3. Differential adjustable from 2 to 6 psig.
4. Rated for resistance loads at 120-V ac.
5. Body and switch housing shall be metal.

B. 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.

C. Instrument Enclosures:

1. Include instrument enclosure for secondary protection to comply with requirements indicated in "Performance Requirements" Article.
2. NRTL listed and labeled to UL 50.
3. Sized to include at least 25 percent spare area on subpanel.
4. Instrument(s) mounted within enclosure on internal subpanel(s).
5. Enclosure face with engraved, laminated phenolic nameplate for each instrument within enclosure.
6. Enclosures housing pneumatic instruments shall include main pressure gage and a branch pressure gage for each pneumatic device, installed inside.
7. Enclosures housing multiple instruments shall route tubing and wiring within enclosure in a raceway having a continuous removable cover.
8. Enclosures larger than [**12 inches**] **<Insert dimension>** shall have a hinged full-size face cover.

Retain subparagraph below for applications requiring additional security.

9. Equip enclosure with lock and common key.

2.29 IDENTIFICATION

A. Control Equipment, Instruments, and Control Devices:

1. [**Self-adhesive label**] [**Laminated acrylic or melamine plastic sign**] bearing unique identification.

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

2. Letter size shall be as follows:

First 12 subparagraphs below are examples only.

a. Operator Workstations: Minimum of [**0.5 inch (13 mm)**] <**Insert dimension**> high.
b. Servers: Minimum of [**0.5 inch (13 mm)**] <**Insert dimension**> high.
c. Printers: Minimum of [**0.5 inch (13 mm)**] <**Insert dimension**> high.
d. DDC Controllers: Minimum of [**0.5 inch (13 mm)**] <**Insert dimension**> high.
e. Gateways: Minimum of [**0.5 inch (13 mm)**] <**Insert dimension**> high.
f. Repeaters: Minimum of [**0.5 inch (13 mm)**] <**Insert dimension**> high.
g. Enclosures: Minimum of [**0.5 inch (13 mm)**] <**Insert dimension**> high.
h. Electrical Power Devices: Minimum of [**0.25 inch (6 mm)**] <**Insert dimension**> high.
i. Accessories: Minimum of [**0.25 inch (6 mm)**] <**Insert dimension**> high.
j. Instruments: Minimum of [**0.25 inch (6 mm)**] <**Insert dimension**> high.
k. Control Damper and Valve Actuators: Minimum of [**0.25 inch (6 mm)**] <**Insert dimension**> high.

3. 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.
4. 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. Raceway and Boxes:

1. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
2. Paint cover plates on junction boxes and conduit same color as the tape banding for conduits. After painting, label cover plate "HVAC Controls," using an engraved phenolic 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 (6 mm)**] <**Insert dimension**>beyond white border.

2.30 SOURCE QUALITY CONTROL

A. Engage with District commissioning agent to evaluate the following according to industry standards for each product, and to verify DDC system reliability specified in performance requirements:

1. DDC controllers.
2. Gateways.
3. Routers.
4. Operator workstations.
5. **<Insert product>**.

B. Product(s) [**and**] [**material(s)**] will be considered defective if [**it does**] [**they do**] not pass tests and inspections.

C. Prepare test and inspection reports.

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 DDC System Provider, 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

Retain "Communication Interface to Equipment with Integral Controls" Paragraph below to require DDC system to monitor or control equipment through a communication link.

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.

Retain "Equipment to Be Connected" Subparagraph below to require equipment to be connected to DDC system through a communication interface; delete if equipment to be connected is indicated on Drawings. Coordinate with Drawings.

   2. Equipment to Be Connected:

Retain applicable subparagraphs below. Coordinate specific interface requirements in Sections specifying equipment.

   a. Air-terminal units specified in Section 23 36 00 "Air Terminal Units."
   b. Kitchen hoods specified in Section 23 38 13 "Commercial-Kitchen Hoods."
   c. Boilers specified in Section 23 52 23 "Cast-Iron Boilers."
   d. Boilers specified in Section 23 52 33 "Water-Tube Boilers."
   e. Boilers specified in Section 23 52 39 "Fire-Tube Boilers."
   f. Chillers specified in Section 23 64 23.11 "Water-Cooled, Scroll Water Chillers."
   g. Chillers specified in Section 23 64 23.21 "Air-Cooled, Scroll Water Chillers."
   h. Chillers specified in Section 23 64 26.11 "Water-Cooled, Rotary-Screw Water Chillers."
   i. Chillers specified in Section 23 64 26.21 "Air-Cooled, Rotary-Screw Water Chillers."
   j. Heat wheels and heat exchangers specified in Section 23 72 00 "Air-to-Air Energy Recovery Equipment."
   k. Air-handling units specified in Section 23 73 13 "Modular Indoor Central-Station Air-Handling Units."
   l. Roof-top units specified in Section 23 74 13 "Packaged, Outdoor, Central-Station Air-Handling Units."
   m. Packaged terminal air-conditioners specified in Section 23 81 13.11 "Packaged Terminal Air-Conditioners, Through-Wall Units," Section 23 81 13.12 "Packaged Terminal Air-Conditioners, Freestanding Units," and Section 23 81 13.13 "Packaged Terminal Air-Conditioners, outdoor, wall-mounted units."

n. Computer-room air-conditioning units specified in Section 238123.11 "Computer-Room Air Conditioners, Floor-Mounted Units (6 Tons (21 kW) And Smaller)."
o. Computer-room air-conditioning units specified in Section 238123.12 "Computer-Room Air Conditioners, Floor-Mounted Units (7 Tons (25 kW) And Larger)."
p. Computer-room air-conditioning units specified in Section 238123.13 "Computer-Room Air Conditioners, Ceiling-Mounted Units."
q. Computer-room air-conditioning units specified in Section 238123.14 "Computer-Room Air Conditioners, Console Units."
r. Computer-room, rack-mounted cooling equipment specified in Section 238123.18 "Computer-Room, Rack-Cooling Equipment."
s. Fan-coil units specified in Section 23 82 19 "Fan Coil Units."
t. Motor-control centers specified in Section 26 24 19 "Motor-Control Centers."
u. Variable-frequency controllers specified in Section 26 29 23 "Variable-Frequency Motor Controllers."
v. Generator sets specified in Section 26 32 13 "Engine Generators."
w. Refrigerant monitoring specified in Section 28 35 00 "Refrigerant Detection and Alarm."
x. **<Insert equipment and Section number and title>**.

Retain "Communication Interface to Other Building Systems" Paragraph below to require DDC system to interface with systems through a communication link.

B. Communication Interface to Other Building Systems:

1. DDC system shall have a communication interface with systems having a communication interface.

Retain "Systems to Be Connected" Subparagraph below to indicate systems to be connected; delete if systems to be connected are indicated on Drawings. Coordinate with Drawings.

2. Systems to Be Connected:

Coordinate specific interface requirements in the Sections retained in remaining subparagraphs below.

a. Title 24 lighting controls specified in Section 260943.16 "Addressable-Luminaire Lighting Controls."
b. Title 24 lighting controls specified in Section 260943.23 "Relay-Based Lighting Controls."
c. Fire-alarm system specified in Section 283111 "Digital, Addressable Fire Alarm System."

3.3 DDC SYSTEM INTERFACE WITH EXISTING SYSTEMS

Retain "Interface with Existing Systems" Paragraph below to require DDC system to be connected to existing systems.

For small remodel projects where the scope is limited to a few rooms, discuss with District Project Manager option to limit specification to controls by the DDC system manufacturer of the existing on-site controls.

A. Interface with Existing Systems:

1. DDC systems shall interface existing systems to achieve integration seamlessly. Replace existing controllers as required to facilitate seamless integration.

Retain "Monitoring and Control of DDC System by Existing Control System" Subparagraph below when DDC system being installed is to integrate with existing system.

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 for existing systems that are not in scope of work and new software for new system.
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 seamlessly.
e. **<Insert requirements>**.

Retain "Integration of Existing Control System into DDC System" Subparagraph below to require existing system to be integrated into DDC system.

3. Integration of Existing Control System into DDC System:

a. Existing control system performance requirements shall be satisfied when monitoring and controlling existing control system through DDC system.
b. Operator shall be able to upload, download, monitor, alarm, report, trend, control and program every input and output point in existing system from DDC system using operator workstations and software provided for existing systems that are not in scope of work and new software for new system.
c. Interface of existing control system I/O points into DDC system shall be transparent to operators. All operational capabilities shall be identical regardless of whether I/O already exists or I/O is being installed.
d. Provide all required software and hardware to integrate the new system with existing systems seamlessly.

e. **<Insert requirements>**.

3.4 CONTROL DEVICES FOR INSTALLATION BY INSTALLERS

Coordinate requirements in this article with requirements in Sections specifying the identified equipment and systems. This article includes examples of requirements but is not all-inclusive. Requirements must be revised to comply with specific Project requirements.

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. For additional requirements, see Part 3 Article “Control Devices for Equipment Manufacturer Factory Installation/Coordination”.

Both paragraphs below are examples only. Retain and revise as applicable.

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

1. DDC control dampers, which are specified in Section 23 09 23.12 "Control Dampers."
2. Airflow sensors and switches, which are specified in Section 23 09 23.14 "Flow Instruments."
3. Pressure sensors, which are specified in Section 23 09 23.23 "Pressure Instruments."
4. **<Insert additional control devices>**.

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

1. DDC control valves, which are specified in Section 23 09 23.11 "Control Valves."
2. Pipe-mounted flow meters, which are specified in Section 23 09 23.14 "Flow Instruments."
3. Pipe-mounted sensors, switches and transmitters. Flow meters are specified in Section 23 09 23.14 "Flow Instruments." Liquid temperature sensors, switches, and transmitters are specified in Section 23 09 23.27 "Temperature Instruments."
4. Tank-mounted sensors, switches and transmitters. Pressure sensors, switches, and transmitters are specified in Section 23 09 23.23 "Pressure Instruments." Liquid temperature sensors, switches, and transmitters are specified in Section 23 09 23.27 "Temperature Instruments."
5. Pipe- and tank-mounted thermowells. Liquid thermowells are specified in Section 23 09 23.27 "Temperature Instruments."
6. **<Insert additional control devices>**.

3.5 CONTROL DEVICES FOR EQUIPMENT MANUFACTURER FACTORY INSTALLATION

A. System Requirements

1. Coordinate with mechanical contactor, HVAC equipment manufacturer(s), DDC System Provider, and DDC system manufacturer, and DDC system component vendor, to ensure that all specified District system requirements are met.
2. Replacing equipment control modules, with a type and brand of control module different than that which came with the equipment, shall not void control module warranty, installation warranty, UL Listings, or any other requirements necessary for a seamlessly integrated DDC system.
3. Certify on General Contractor's letterhead that:
   a. equipment control module installation has been coordinated
   b. warranty covers entire system, including equipment and controls interface
   c. equipment and controls comply with UL Listings
   d. all requirements for providing a complete, seamlessly integrated DDC system have been met
4. Certificate shall be signed by all parties involved with providing a seamlessly integrated DDC system, including General Contractor, DDC System Provider, equipment manufacturers, controls manufacturer, vendors, installers, etc.

Paragraphs below are examples only. Retain and revise as applicable.

B. HVAC Controls Configuration

1. [**HVAC equipment manufacturer's controls module**.]
2. [**Separate controls module on HVAC equipment**.]
3. [**Separate controls module at thermostat**.]

C. Components for Delivery to Factory

1. Deliver the following to air-handling unit manufacturer for factory installation. Include installation instructions to air-handling unit manufacturer[**and supervise installation for compliance with requirements**].

   a. **[Programmable application] [or] [application-specific]** controller.
   b. Unit-mounted DDC control dampers and actuators, which are specified in Section 23 09 23.12 "Control Dampers."
   c. Unit-mounted airflow sensors, switches and transmitters, which are specified in Section 23 09 23.14 "Flow Instruments."
   d. Unit-mounted gas sensors and transmitters, which are specified in Section 23 09 23.16 "Gas Instruments."
   e. Unit-mounted leak-detection switches, which are specified in Section 23 09 23.18 "Leak-Detection Instruments."
   f. Unit-mounted speed sensors, switches and transmitters, which are specified in Section 23 09 23.24 "Speed Instruments."
   g. Unit-mounted pressure sensors, switches and transmitters, which are specified in Section 23 09 23.23 "Pressure Instruments."

h. Unit-mounted temperature sensors, switches and transmitters, which are specified in Section 23 09 23.27 "Temperature Instruments."
i. Relays.
j. Warranty and UL listing (for information and coordination purposes).
k. **<Insert additional control devices>**.

2. Deliver the following to terminal unit manufacturer for factory installation. Include installation instructions to terminal unit manufacturer.
   a. [Programmable application] [or] [application-specific] controller.
   b. Electric damper actuator. Dampers actuators are specified in Section 23 09 23.12 "Control Dampers."
   c. Unit-mounted flow and pressure sensors, transmitters and transducers. Flow sensors, transmitters, and transducers are specified in Section 23 09 23.14 "Flow Instruments." Pressure sensors, switches, and transmitters are specified in Section 23 09 23.23 "Pressure Instruments."
   d. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section 23 09 23.27 "Temperature Instruments."
   e. Relays.
   f. Warranty and UL listing (for information and coordination purposes).
   g. <Insert additional control devices>.
3. Deliver the following to fan-coil unit manufacturer for factory installation. Include installation instructions to fan-coil unit manufacturer.
   a. [Programmable application] [or] [application-specific] controller.
   b. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section 23 09 23.27 "Temperature Instruments."
   c. Flow and pressure switches. Air and liquid flow sensors, transmitters, and transducers are specified in Section 23 09 23.14 "Flow Instruments." Pressure sensors, switches, and transmitters are specified in Section 23 09 23.23 "Pressure Instruments."
   d. Leak-detection switches, which are specified in Section 23 09 23.18 "Leak-Detection Instruments."
   e. Relays.
   f. Warranty and UL listing (for information and coordination purposes).
   g. <Insert additional control devices>.

3.6 GENERAL INSTALLATION REQUIREMENTS

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

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

C. Support products, tubing, piping wiring and raceways. Brace products to prevent lateral movement and sway or a break in attachment.

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 07 84 13 "Penetration Firestopping."

F. Seal penetrations made in acoustically rated assemblies. Comply with requirements in Section 07 92 00 "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.

3.7 OPERATOR WORKSTATION INSTALLATION

A. Desktop Operator Workstations Installation:

If multiple desktop operator workstations with different requirements are required, revise subparagraphs below to match requirements in "Desktop Operator Workstations" Article.

1. Install operator workstation(s) at location(s) directed by District.
2. Install multiple-receptacle power strip with cord for use in connecting multiple operator workstation components to a single duplex electrical power receptacle.
3. Provide all required software on operator workstation(s). Verify software functions properly. 30 days after testing system locally at Project site, work together with District personnel to install all required software on District server.
4. Develop Project-specific graphics, trends, reports, logs and historical database.

B. Portable Operator workstations Installation:

If multiple portable operator workstations with different requirements are required, revise subparagraphs below to match requirements in "Portable Operator Workstations" Article.

1. Turn over portable operator workstations to District at Substantial Completion.
2. Install software on operator 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 District's[**and Architect's**] review before creating graphic using graphics software.
5. Seek District input in graphics development once using graphics software.
6. Final editing shall be done on-site with District's[**and Architect's**] review and feedback.
7. Refine graphics as necessary for District acceptance.
8. On receiving District 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.

3.8 PRINTER INSTALLATION

A. Provide the following printer(s) at location(s) directed by District:

Retain if printers are not indicated on Drawings.

1. Color Laser: Quantity, [**one**] [**one per desktop operator workstation**] **<Insert quantity>**.

B. Install printer software on operator workstations and verify that software functions properly.

3.9 GATEWAY INSTALLATION

Design of each gateway should include an interoperability schedule showing each point or event with interface requirements defined for each.

For BACnet DDC systems, include an interoperability schedule showing each point or event on non-BACnet side that BACnet "client" will read, and each parameter that BACnet network will write to for BACnet services, or BIBBs defined in ASHRAE 135, Annex K.

A. Install gateways if required for DDC system communication interface requirements indicated.

Location must be determined during design phase and adequately indicated on Drawings or in Project Specifications.

1. Install gateway(s) required to suit indicated requirements:

    a. **<Insert requirements>**.

B. Test gateway to verify that communication interface functions properly.

3.10 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.

3.11 CONTROLLER INSTALLATION

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

B. Connect controllers to field power supply.

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

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

E. Installation of Network Controllers:

1. Quantity and location of network controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
2. Install controllers in a protected location that is easily accessible by operators.
3. Top of controller shall be within [**72 inches**] [**84 inches**] **<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**] [**84 inches**] **<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.

3.12 ENCLOSURES INSTALLATION

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

Retain applicable devices in subparagraphs below.

1. Gateways.
2. Routers.
3. Controllers.
4. Electrical power devices.
5. Relays.
6. Accessories.
7. Instruments.
8. Actuators
9. **<Insert devices>**.

B. Attach wall-mounted enclosures to wall using the following types of steel struts:

1. For NEMA 250, Type 1 Enclosures: Use [**painted steel**] [**galvanized-steel**] [**corrosion-resistant-coated steel**] strut and hardware.
2. For NEMA 250, Type 4 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.

Retain paragraph below to require wireways to connect between adjacent enclosures. Wireways provide a neat and easily accessible alternative to conduit, but they may come at a higher cost for specific installation.

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. Provide and connect electrical power to DDC system products requiring electrical power, whether power is specifically indicated on drawings or not. Work shall comply with NFPA 70 and other requirements indicated.

B. Comply with requirements in Section 26 28 16 "Enclosed Switches and Circuit Breakers" for electrical power circuit breakers.

C. Comply with requirements in Section 26 05 19 "Low-Voltage Electrical Power Conductors and Cables" for electrical power conductors and cables.

D. Comply with requirements in Section 26 05 33 "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.

Products in first paragraph below are described in Section 260553 "Identification for Electrical Systems."

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. 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.

Retain first two paragraphs below to enhance locating products installed above ceilings.

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 balanced twisted pair 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>**.

B. 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>**.

C. 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 District and provide unique naming and addressing for networks and devices.

Retain "ASHRAE 135 Networks" Paragraph below for unique requirements to ASHRAE 135 networks.

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 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 DDC system installer's discretion but must be approved by District in advance, be documented and be unique for like object types within device.

3.17 CONTROL WIRE, CABLE AND RACEWAYS INSTALLATION

A. Comply with NECA 1.

B. Conduit Installation:

1. Comply with Section 26 05 33 "Raceways and Boxes for Electrical Systems" for control-voltage conductors.
2. Comply with Section 27 05 28 "Pathways for Communications Systems" for balanced twisted pair cabling and optical fiber installation.

C. Wire and Cable Installation:

1. Comply with installation requirements in Section 26 05 23 "Control-Voltage Electrical Power Cables."
2. Comply with installation requirements in Section 27 13 13 "Communications Copper Backbone Cabling."
3. Comply with installation requirements in Section 27 15 13 "Communications Copper Horizontal Cabling."

Requirements below are in addition to those specified in the Division 26 and 27 cabling sections.

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.

3.18 FIELD QUALITY CONTROL

Retain "Testing Agency," "DDC System Manufacturer's Field Service," and "Perform the following tests and inspections" paragraphs below to identify who shall perform tests and inspections. Discuss with District Project Manager how tests and inspections will be handled for this project, which entity/entities will be responsible for which test and inspections for this project, and edit specifications accordingly.

A. Testing Agency: District Commissioning Agent shall perform tests and inspections. Collaborate with Commissioning Agent to facilitate performance.

Retain "DDC System Manufacturer's Field Service" Paragraph below to require a factory-authorized service representative to perform tests and inspections.

B. DDC System Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.

Retain "Perform the following tests and inspections" Paragraph below to require Contractor to perform tests and inspections.

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.

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 cable 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.

3.19 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. 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.

3.20 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 instrument 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 damper 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 damper 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 control valve 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 control valve 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.

3.21 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 a backup power source.
5. 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.

3.22 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.

3.23 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.

Retain first subparagraph below if applicable to Project.

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.
8. Work with District IT staff to install all required software on District server, and run validation test.

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.

3.24 COMMISSIONING AGENT SUPPORT

A. Coordinate with, and provide on-site support to, District Commissioning Agent.

B. Review the Commissioning Plan. Satisfy, include, and provide all DDC System Contractor services and products necessary for complete installation.

3.25 FINAL REVIEW

A. Submit written request to District 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 District 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 Provider 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 Provider 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:

Subparagraphs below are examples only and must be revised to suit Project.

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 operator workstation and mobile device. Show that maintenance personnel interface tools perform as indicated in DDC system 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.

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 operator 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 District. 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>**.

3.26 SOFTWARE SERVICE AGREEMENT

A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for two year(s).

B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within two 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 days to allow District to schedule and access system and to upgrade computer equipment if necessary.

3.27 DEMONSTRATION

Revise this article to suit scope of DDC system for Project. Not all requirements indicated may be applicable.

A. Engage a factory-authorized service representative with complete knowledge of Project-specific system installed to train District'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 District of anticipated training requirements if more than minimum training requirements are indicated.
3. Minimum Training Requirements:

Revise subparagraphs below to suit unique requirements of DDC system and other Project requirements. Consult District for assistance in establishing minimum requirements.

a. Provide not less than five days of training total.
b. Stagger training over multiple training classes to accommodate District'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 District [**20**] **<Insert number>** business days before expected Substantial Completion.
2. Schedule training to provide District with at least 10 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-minute break between sessions. Morning and afternoon sessions shall be separated by 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 District.

D. Training Attendee List and Sign-in Sheet:

1. Request from District 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 District 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 attendees.
2. Make allowance for District to add up to one 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:

Revise subparagraphs below to suit District personnel being trained. Consult District for assistance.

1. High school education and degree.
2. Basic user knowledge of computers and office applications.
3. Basic knowledge of HVAC systems.
4. Basic knowledge of DDC systems.
5. Basic 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 District 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. District 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 District.
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 operator 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.

Retain first subparagraph below only if DDC system is capable of remote access.

2. Provide capability to remotely access to Project DDC system for use in training.
3. Provide an operator workstation for use by each attendee.

M. Training Content for Daily Operators:

Subparagraphs below are examples only and must be revised to suit Project.

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:

Subparagraphs below are examples only and must be revised to suit Project.

1. Making and changing operator 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, operator 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:

Subparagraphs below are examples only and must be revised to suit Project.

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. Operator 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 District with [**two**] **<Insert number>** copies of digital files on DVDs or flash drives for later reference and for use in future training.
4. District retains right to make additional copies for intended training purposes without having to pay royalties.

END OF SECTION 23 09 23

Retain this notice in all Sections of Project Manual.

San Diego Unified School District Guide Specifications
Section Version August 2018 (Bulletin)