**SECTION 23 09 23**

**DIRECT DIGITAL CONTROL SYSTEM FOR HVAC**

**BASED ON DFD MASTER SPECIFICATION DATED 3/28/2023**

***This section has been written to cover most (but not all) situations that you will encounter. Depending on the requirements of your specific project, you may have to add material, delete items, or modify what is currently written. The Division of Facilities Development expects changes and comments from you. This section should be used for new or existing facilities where an open bid of DDC controls is warranted. Contact the Division of Facilities Development if there is a question as to whether this should be done.***

**P A R T 1 - G E N E R A L**

**SCOPE**

Work in this section includes Direct Digital Control (DDC) panels, main communication trunk, software programming, and other equipment and accessories necessary to constitute a complete Direct Digital Control (DDC) system. This system interfaced with pneumatic/electric controls (Section 23 09 14) utilizing Direct Digital Control signals to operate actuated control devices will meet, in every respect, all operational and quality standards specified herein.

PART 1 - GENERAL

 Scope

 Related Work

 Reference

 Reference Standards

 Work Not Included

 Quality Assurance

 Submittals

 Operation and Maintenance Data

 Material Delivery and Storage

PART 2 - PRODUCTS

 General

 Local Control Panels

 Direct Digital Controls (DDC)

 Networking/Communications

 BACnet Requirements

 Supervisory Controllers

 Software License Agreement

 System Software Features

 Programmable Controllers

 Application Specific Controllers - HVAC

 Operator Interface Requirements

 Operator Workstation & DDC Server

 Web Based HTML Browser Interface

 Portable Operator Terminal

 ASC Portable Service Terminal

 Uninterruptible Power Supply

PART 3 - EXECUTION

 General

 Installation

 Preconstruction Review Meeting

Construction Verification

 Functional Performance Testing

Agency Training

**RELATED WORK**

Applicable provisions of Division 1 govern work under this Section.

Section 01 91 01 or 01 91 02 – Commissioning Process

Section 23 05 93 - Testing, Adjusting, and Balancing for HVAC – Coordination

Section 23 08 00 – Commissioning of HVAC

Section 23 09 14 - Pneumatic and Electric Instrumentation and Control Devices for HVAC

Section 23 09 15 - Direct Digital Control Input/Output Point Summary Tables

Section 23 09 93 - Control Sequences

Division 23 - HVAC - Equipment provided to be controlled or monitored

Division 26 - Electrical - Equipment provided to be controlled or monitored

**REFERENCE**

Applicable provisions of Division 1 govern work under this section.

**REFERENCE STANDARDS**

FCC Part 15, Subpart J, Class A - Digital Electronic Equipment to Radio Communication Interference

**WORK NOT INCLUDED*The A/E must properly coordinate the necessary power wiring.***

Section 23 09 14 work includes furnishing and installing all field devices, including electronic sensors for the DDC of this section, equipment, and all related field wiring, interlocking control wiring between equipment, pneumatic tubing, sensor mounting, etc., that is covered in that section.

Motorized control dampers and actuators, thermowells (temperature sensing wells), automatic control valves and their actuators are also covered in Section 23 09 14.

**QUALITY ASSURANCE**

MANUFACTURER:

A firm regularly engaged in manufacture of DDC control equipment similar to the specified equipment and has been in satisfactory similar service for not less than 8 years.

INSTALLER:

A firm specializing and experienced in DDC control system installation for no less than 3 years. All engineering and commissioning work shall be done by qualified employees of this manufacturer, or qualified employees of an Authorized Representative of that manufacturer that provides engineering and commissioning of the manufacturer’s control equipment. Where installing contractor is an authorized representative of the control equipment manufacturer, submit written confirmation of such authorization. Indicate in letter of authorization that the installing contractor has successfully completed all necessary training required for the engineering, installation, and commissioning of equipment and systems to be provided for the project and that such authorization has been in effect for a period of not less than three years. The letter of authorization should also indicate that the installing contractor is authorized to install the manufacturer’s DDC equipment at the project location at the time the project is bid. Installation of the equipment shall be done by qualified mechanics and/or electricians in the direct employ or be directly subcontracted and under the supervision of the manufacturer or Authorized Representative. The contractor providing and installing the equipment under this specification section shall be the same contractor providing and installing equipment under the 23 09 14 specification section.

RESPONSE TIME:

During warrantee period, four (4) hours or less, 24-hours/day, 7 days/week.

ELECTRICAL STANDARDS:

Provide electrical products, which have been tested, listed and labeled by Underwriters' Laboratories (UL) and comply with NEMA standards.

DDC Standards: DDC manufacturer shall provide written proof with shop drawings that the equipment being provided is in compliance with F.C.C. rules governing the control of interference caused by Digital Electronic Equipment to Radio Communications (Part 15, Subpart J, Class A).

**SUBMITTALS**

Include the following information:

Details of construction, layout, and location of each temperature control panel within the building, including instrument’s location in panel and labelling. Indicate which piece of mechanical equipment is associated with each controller and what area within the building is being served by that equipment. For terminal unit control, provide a room schedule that would list mechanical equipment tag, room number of space served, address of DDC controller, and any other pertinent information required for service.

PRODUCT DATA

Submit manufacturer's specifications for each control device furnished, including installation instructions and start-up instructions. General catalog sheets showing a series of the same device is not acceptable unless the specific model is clearly marked. Annotated software program documentation shall be submitted for system sequences, along with descriptive narratives of the sequence of operation of the entire system involved. Submit wiring diagram for each electrical control device along with other details required to demonstrate that the system has been coordinated and will function as a system.

MAINTENANCE DATA

Submit maintenance data and spare parts lists for each control device. Include this data in maintenance manual.

RECORD DRAWINGS

Prior to request for final payment provide complete composite record drawings to incorporate the DDC and Pneumatic/Electric field work. All software addressing for device communication shall be noted for all devices provided under this section and the communication addressing required for devices provided by others that are integrated into the direct digital control system provided under this section. Point to point routing of communication trunks and power wiring between DDC controllers, DDC communication devices, control panels, and Ethernet switches shall be documented. For systems that have additions to existing communication networks, provide complete DDC network diagrams for the entire building with new work clearly delineated. Coordinate with the supplier of the equipment specified to be interfaced through digital communications for communication addressing. Provide circuit number of 120VAC panel power circuit(s) feeding each control panel on record drawings. Label circuit number(s) inside the panel served.

# OPERATION AND MAINTENANCE DATA

All operations and maintenance data shall comply with the submission and content requirements specified under section GENERAL REQUIREMENTS.

***Delete the following if there are no additional requirements.***

In addition to the general content specified under GENERAL REQUIREMENTS supply the following additional documentation:

1. ***[A/E and commissioning provider to define detailed operation and maintenance data requirements for equipment specifications added to this section.]***

**MATERIAL DELIVERY AND STORAGE**

Provide factory shipping cartons for each piece of equipment and control device. This contractor is responsible for storage of equipment and materials inside and protected from the weather.

**P A R T 2 - P R O D U C T S**

**GENERAL**

Provide DDC control products in sizes and of capacities as required, conforming to manufacturer's standard materials and components as published in their product information, designed, and constructed as recommended by the manufacturer and as required for application indicate.

System shall be capable of operating with 120 VAC power supply, fully protected with a shutdown-restart circuit, and associated hardware and software.

All DDC controllers shall use screw terminals for termination of individual wires. Spade lugs are not acceptable.

**LOCAL CONTROL PANELS**

Use control panels with suitable mounting brackets for each supply fan system. Locate panel adjacent to system served.

Fabricate panels of 14-gauge furniture grade steel or 6063-T5 extruded aluminum alloy, totally enclosed on six sides, hinged door, and keyed lock, with manufacturer's standard shop painted finish and color.

Provide UL listed cabinets for use with line voltage devices.

Control panels that have devices or terminations that are fed or switch 50V or higher shall enclose the devices, terminations, and wiring so that Personal Protective Equipment (PPE) is not required to service the under 50V devices and terminations within the control panel. As an alternative, a separate panel for only the 50V and higher devices may be provided and mounted adjacent to the under 50V control panel. For DDC controllers that are directly fed by 120VAC, provide an externally mounted 120VAC, 5A fast blow fuse to feed these controllers.

Plastic control enclosures will be approved provided all conduits are bonded and grounded.

Provide control panels for all DDC Controllers, ASC’s, and associated function modules. All controls to be in control panels provided under this Section except for the following:

* Terminal unit controllers mounted within the terminal unit equipment enclosure as specified under Section 23 09 14.
* Above accessible lay-in tile ceilings where VAV box controllers designed to be directly mounted on air terminals.
* Above accessible lay-in tile ceilings where additional controllers are required for air terminal unit control. Where additional controllers are required, they shall not be mounted directly to the ductwork but be mounted on din rail or back panel in an accessible location as close as possible to the terminal unit(s) being controlled.
* Any devices other than DDC controllers, i.e., relays, pressure switches, etc. shall be installed in an enclosure.
* Enclosures provided under Section 23 36 00 for VAV terminals not mounted above accessible lay-in ceilings. Coordinate with the Division 23 contractor to ensure the controllers provided under Section 23 36 00 are of sufficient size to house the controller required for control of the terminal unit. If additional controllers are required to control other associated terminal units and the enclosure provided under Section 23 36 00 is not of sufficient size, this contractor shall provide an additional enclosure to be mounted adjacent to the terminal unit provided enclosure.

All wiring for controllers shall be managed in a neat and workmanlike manner.

Permanently label all controls; tag all control wiring and document both on control drawings.

**DIRECT DIGITAL CONTROLS**

System to be capable of integrating multiple building functions, including equipment supervision and control, alarm management, energy management, and trend data collection.

DDC to consist of Supervisory Controllers, Programmable Controllers, stand-alone Application Specific Controllers (ASC's), Operators Terminals, Operator Workstations, DDC system servers, and other operator interface devices.

The vendor of the system provided under this Section shall provide all software and communication interface hardware necessary to program and upload/download programmable and application specific controllers from a laptop computer and make additional copies and future software revisions available for sale directly to the user Agency.

The system shall be modular in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, ASC's, and operator devices.

The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

**NETWORKING/COMMUNICATIONS**

The design of the DDC shall be networked. The highest-level networking shall use Ethernet and the sub-level networking shall use serial or Ethernet communications. Inherent in the system's design shall be the ability to expand or modify the highest network either via a local area network (LAN), wide area network (WAN), or a combination of the two schemes.

The highest-level DDC communications network shall be capable of direct connection to and communication with a high-speed LAN or WAN utilizing an Ethernet connection.

The supervisory controller shall directly oversee a local network such that communications may be executed directly to and between programmable controllers and ASC's. All operator devices shall have the ability to access all points and application reports on the network.

Provide serial or Ethernet communication ports on all ASC's for operator's terminal communications with the DDC Controller.

Access to system data shall not be restricted by the hardware configuration of the DDC system.

Global data sharing or global point broadcasting shall allow point data to be shared between programmable controllers and ASC's when it would be impractical to locate multiple sensors.

Network design shall include the following provisions:

1. Data transfer rates for alarm reporting and quick point status from multiple programmable controllers and ASC's. The minimum baud rate shall be 9600 baud.
2. Support of any combination of programmable controllers and ASC's. A minimum of 32 programmable controllers and ASC's shall be supported on a single local network. The buss shall be addressable for up to 32 ASC's.
3. Detection of single or multiple failures of ASC's or the network media.
4. Error detection, correction, and re-transmission to guarantee data integrity.
5. Use commonly available, multiple-sourced, networking components.
6. Use of an industry standard communication transport, such as, ARCNET, Ethernet, and IEEE RS-485 communications interface.

Provide a temporary Ethernet network for communications between supervisory controllers and operator workstation until the building IT network is available for use by the DDC system. The temporary Ethernet network and all other communications required for the DDC system shall be installed as required for specified operation of mechanical equipment so check out and commissioning of the equipment can occur in a timely manner.

**BACNET REQUIREMENTS**

BACnet of highest-level network communications shall be capable of BACnet/IP over Ethernet and field level communications shall utilize BACnet MSTP or BACnet/IP.

All controllers shall provide a Protocol Implementation Conformance Statement (PICS) and BACnet Interoperability Building Blocks (BIBB”S) as required by the American National Standards Institute/American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ANSI/ASHRAE) Standard 135-2001, BACnet protocol.

In general, all devices shall support the following:

Segmentation Capability

Segmentation requests supported

Segmentation responses supported

 Standard Object Types Supported

1. Analog input
2. Analog output
3. Analog value
4. Binary input
5. Binary output
6. Binary value
7. Calendar
8. Device
9. Event enrollment
10. Group
11. Multistate input
12. Multistate output
13. Multistate value
14. Notification class
15. Schedule

Character Sets supported

1. ANSI X3.4
2. ISO 10646 Universal Character Set-2

All highest level networked supervisory devices shall support the following:

Data Link Layer Option

1. BACnet Internet Protocol (IP) (Annex J)

Networking Options

BACnet/IP Broadcast Management Device (BBDM)

BACnet object name and description shall match the existing naming conventions used by the state Agency for their existing Building Automation System. Coordinate with Agency control personnel to establish the naming conventions prior to programming of any controllers provided under this specification section. All controllers shall have object names, descriptions, and engineering units that are writable at the controller level and shall be programmed so that the object names, descriptions, and engineering units match the desired naming standards as specified above. Ensure that the BACnet object attributes for object name, object description, engineering units and other required attributes will be transferred through to the Supervisory Controller when the auto-discovery function is executed.

Coordinate BACnet device instance numbering with the agency facility personnel for controllers provided under this Section that are being connected to an existing building automation system. This contractor shall be responsible for correcting any conflicts with existing devices that may occur or changing the device instance numbers to comply to follow the agency BACnet device instance numbering scheme.

The following table indicates the minimum VAV terminal unit objects, the associated naming, and the object values that are required to be writable that shall be provided for all VAV terminals. If the agency does not have a convention for VAV terminal object names and descriptions that it prefers, use the naming standards as listed below. Provide similar naming and descriptions that are approved by the agency for other types of terminal units and mechanical systems.

Object Type Object Name Object Description Units Writeable

BV DEVICE-S DEVICE STATUS - SERVED BY AHU# ONLINE/OFFLINE

MV OCC-MODE OCCUPIED MODE OCC/UNOCC/STNDBY

BV OCC-SCHED OCCUPIED SCHEDULE Xam-Xpm OCC/UNOCC Yes

DI OCC-S OCCUPANCY SENSOR STATUS OCC/UNOCC

AV ZN-SP ZONE TEMPERATURE SETPOINT DEG F Yes

AI RM#-T ROOM #### TEMPERATURE DEG F

AI DA-T DISCHARGE AIR TEMPERATURE DEG F

AO HTG-VLV HEATING VALVE % OPEN Yes

AO RAD-VLV RADIATION VALVE % OPEN Yes

AO SA-DPR SUPPLY AIR DAMPER % OPEN Yes

AV CFM-SP ACTUAL FLOW SETPOINT CFM

AI CFM-FLOW SUPPLY AIR FLOW CFM

AV HTG-SP HEATING TEMPERATURE SETPOINT DEG F Yes

AV CLG-SP COOLING TEMPERATURE SETPOINT DEG F Yes

AV OCC-C-CFM-MIN OCCUPIED CLG CFM MIN SETPOINT CFM Yes

AV OCC-C-CFM-MAX OCCUPIED CLG CFM MAX SETPOINT CFM Yes

**SUPERVISORY CONTROLLERS**

Supervisory controllers shall be microprocessor-based, multi-tasking, multi-user, and digital control processors.

If the system being provided is Niagara based, it shall be provided with open connectivity to any manufacturers BACnet programmable or application specific direct digital controllers. These controllers shall be JACE 8000 series models or the identical hardware private label equivalent. The programmable controllers and application specific controllers provided under this Section shall be able to be programmed by their respective engineering software application tools through the Niagara based supervisory controllers from the Ethernet level network. The engineering software application tools shall be able to be loaded on a personal computer with Ethernet connectivity and no additional hardware shall be required to connect to and download any programmable or application specific controller.

The contractor shall provide all labor to build the supervisory controller database in conjunction with and under the supervision of the Agency control personnel. Naming conventions, database structure, and global application strategies shall be reviewed and approved by the Agency control personnel before implementation.

Each supervisory controller shall have sufficient memory to support its own operating system and databases including:

1. Control processes
2. Energy management application
3. Alarm management
4. Trend data
5. Maintenance support applications
6. Operator I/O
7. Dial-up communications
8. Manual override monitoring

The system shall be modular in nature and shall permit easy expansion through the addition of field controllers, sensors, and actuators.

Supervisory controllers shall provide at least two RS-232C or USB serial communication ports or Ethernet ports for simultaneous operation of multiple operator I/O devices, such as laptop computers, personal computers, and video display terminals.

Supervisory controllers shall monitor the status of all overrides and include this information in the logs and summaries to inform the operator that automatic control has been inhibited.

Each supervisory controller shall continuously perform self-diagnostics, communications diagnostics, and diagnostics of all subsidiary equipment. Supervisory controllers shall provide both local and remote annunciation of any detected component failures, or repeated failure to establish communication. Indication of the diagnostic results shall be provided at each supervisory controller.

Isolation shall be provided at all network terminations, as well as all field point terminations, to suppress induced voltage transients consistent with IEEE Standard 587-1980. Isolation levels shall be sufficiently high to allow all signal wiring to be run in the same conduit as high voltage wiring acceptable by electrical code.

In the event of the loss of normal power, there shall be an orderly shutdown of the supervisory controller to prevent the loss of data base or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data, and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.

Upon restoration of normal power, the supervisory controller shall automatically resume full operation without manual intervention.

Should supervisory controller memory be lost for any reason, the supervisory controller shall have the capability of reloading it’s programming via high-speed local area network from the control system archive workstation or server, the local RS-232C port, or telephone line dial-in.

If a supervisory controllers require a software license, this contractor shall provide all labor and software upgrades required so that the manufacturer’s current software revision is provided for one year after the project completion date of the project as stated in the project contract documents.

***Delete the following paragraph for DDC systems that are not Niagara based. Some of the systems that can be Niagara based are: Siemens Talon, Tridium, Honeywell Spyder, Alerton, Invensys IA, Distech, American AutoMatrix. If the specification is open to all vendors, leave the following paragraph in the Section.***

**SOFTWARE LICENSE AGREEMENT**

For Niagara based systems, it is the express goal of this specification to implement an open system that will allow products from various suppliers to be integrated into a unified system in order to provide flexibility for expansion, maintenance, and service of the system. The user Agency shall be the named license holder of all software associated with any and all incremental work on the project(s). All Niagara software licenses shall have the “accept.station.in=\*”; “accept.station.out=\*” and “accept.wb.in=\*” and “accept.wb.out=\*” section of the software licenses. The intent is to ensure that the installed Niagara products may be completely open for integrations. The user Agency shall be free to direct the modification of the any software license, regardless of supplier. In addition, the user Agency shall receive ownership of all job specific software configuration documentation, data files, and application-level software developed for the project. This shall include all custom, job specific software code and documentation for all configuration and programming that is generated for a given project and /or configured for use within Niagara Framework (Niagara) based controllers and/or servers and any related LAN / WAN / Intranet and Internet connected routers and devices. Any and all required Ids and passwords for access to any component or software program shall be provided to the user Agency. Provide all software necessary for developing software algorithms in all supervisory, programmable, and application specific direct digital controllers which is licensed to the owner

Programming tools for programmable and application specific controllers that utilize the Niagara Framework shall not be restricted to any specific brand of Jace. Tools and controllers shall be able to connect to any brand of Jace that are provided under this specification Section.

**SYSTEM SOFTWARE FEATURES**

All necessary software to form a complete operating system, as described in this specification, shall be provided as an integral part of the supervisory controller, and shall not be dependent upon higher level computer for execution.

Control software shall include a provision for limiting the number of times that each piece of equipment may be cycled within any one-hour period.

The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads.

Supervisory controllers shall have the ability to perform any or all of the following energy management routines:

1. Time of day scheduling
2. Calendar based scheduling
3. Holiday scheduling
4. Optimal start
5. Optimal stop
6. Demand limiting
7. Load rolling
8. Heating/cooling interlock

All programs to be executed automatically without the need for operator intervention, and be flexible enough to allow user customization. Programs shall be applied to building equipment described in Section 23 09 93 of this specification.

Supervisory controllers shall be able to execute configured processes defined by the user to automatically perform calculations and control routines.

It shall be possible to use any of the following in a configured process:

1. Any system-measured point data or status
2. Any calculated data
3. Any results from other processes
4. Boolean logic operators (and, or)

Configured processes may be triggered based on any combination of the following:

1. Time of day
2. Calendar date
3. Other processes
4. Events (e.g., point alarms)

A single process shall be able to incorporate measured or calculated data from any and all other ASC's.

A single process shall be able to issue commands to points in any and all other programmable controllers and ASC's on the local network.

Alarm management shall be provided to monitor, buffer, and direct alarm reports to operator devices and memory files. Each supervisory controller shall perform distributed; independent alarm analysis and filtering to minimize network traffic and prevent alarms from being lost. At no time shall the ability of supervisory controllers to report alarms be affected by either operator activity at the local I/O device or communications with other ASC's on the network.

All alarm or point change reports shall include the English language description of each point and the time and date of the occurrence.

The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of three priority levels shall be provided. Users shall have the ability to manually inhibit alarm reporting for each point.

The user shall also be able to define conditions under which point changes need to be acknowledged by an operator and/or logged for analysis at a later date.

Alarms reports and messages shall be directed to an operator device.

In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 60-character alarm message to more fully describe the alarm condition or direct operator response.

Each supervisory controller shall be capable of storing a library of at least 100 messages. Each message may be assignable to any number of points in the panel.

A data collection utility shall be provided to automatically sample, store, and display system data.

Measured and calculated analog and binary data shall be assignable to user definable trends for the purpose of collecting operator specified performance data over extended periods of time. Sample intervals of 1 minute to 24 hours, in one minute or one hour intervals, shall be provided. Each supervisory controller shall have a dedicated buffer for trend data and shall be capable of storing 16 trend logs. Each trend log shall have up to four points trended at 48 data samples each. Data shall be stored at the supervisory controller and up-loaded to the DDC system server when archiving is desired.

Supervisory controllers shall automatically accumulate and store runtime hours for binary input and output points specified in Section 23 09 14 of this specification.

Supervisory controllers shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis, user defined, for user-selected analog and binary pulse input type points.

Totalization shall provide calculation and storage accumulations of up to 9,999,999 units (e.g., KWH, gallons KBTU, tons, etc.).

The totalization routine shall have a sampling resolution of one minute.

The user shall have the ability to define a warning limit. Unique, user specified messages shall be generated when the limit is reached.

The information available from pulse totalization shall include, but not be limited to, the following:

1. Peak demand, with date and time stamp
2. 24-hour demand log
3. Accumulated KWH for day
4. Sunday through Saturday KWH usage
5. Demand KW annual history for past 12 periods
6. KWH annual history for past periods

Supervisory controllers shall have the ability to count events, such as the number of times a pump or fan system is cycled on and off.

The event totalization feature shall be able to store the records associated with a minimum of 9,999,999 events before reset.

**PROGRAMMABLE CONTROLLERS**

Programmable controllers shall be provided with a software program that shall allow the user to design flexible software algorithms for the control sequences as described in Sections 23 09 14 and 23 09 93 portions of this specification.

Programmable controllers shall support all necessary point inputs and outputs to perform the specified control sequence in a totally stand-alone fashion.

Each programmable controller shall perform its own limit and status monitoring and analysis to maximize network performance by reducing unnecessary communications.

Each programmable controller shall support the use of a locally mounted status and adjust panel interface to allow for the local adjustment of all setpoints, temporary override of any input or output points and status of all points directly at the controller. The capabilities of the locally mounted status and adjust panel shall include, but not be limited to, the following information for the programmable controllers to which:

1. Display temperatures
2. Display status
3. Display setpoints
4. Display control parameters
5. Override binary output control
6. Override analog output control
7. Override analog setpoints
8. Modification of gain and offset constants

All system setpoints, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the programmable controller.

Programmable controllers shall support, but not be limited to, the following configurations of systems to address current requirements as described in Sections 23 09 14 and 23 09 93 portions of this specification, and for future expansion of air handling units:

1. Mixed air handling units
2. 100 percent outside air handling units
3. Boiler or chiller plants with pump logic
4. Hot water heat exchangers
5. Cooling towers
6. Zone pressurization of labs
7. Smoke control systems
8. Generic system interlocking through hardware

**APPLICATION SPECIFIC CONTROLLERS - HVAC APPLICATIONS**

Each supervisory controller shall be able to extend its monitoring and control through the use of stand-alone application specific controllers (ASC's).

Each ASC shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each ASC shall be a microprocessor based, multi-tasking, real-time digital control processor.

Each ASC shall have sufficient memory to support its own operating system and databases including:

1. Control Processes
2. Energy Management Applications
3. Operator I/O (Portable Service Terminal)

The operator interface to any ASC point or program shall be through the supervisory controller connection to any ASC on the network.

ASC's shall directly support the temporary use of a portable service terminal that can be connected to the ASC via zone temperature or directly at the controller. The capabilities of the portable service terminal shall include, but not be limited to, the following information for the:

1. Display temperatures
2. Display status
3. Display setpoints
4. Display control parameters
5. Override binary output control
6. Override analog output control
7. Override analog setpoints
8. Modification of gain and offset constants

All system setpoints, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the ASC.

ASC’s shall support, but not be limited to, the following configurations of systems to address current requirements as described in Sections 23 09 14 and 23 09 93 portions of this specification, and for future expansion of air handling units:

1. Variable Air Volume Terminals
2. Reheat Terminals
3. Fan Coils
4. Unit Ventilators
5. Packaged Air Handling Units

For butterfly type Variable Air Volume (VAV) Terminals, provide differential pressure transducers and damper actuators for flow measurement and actuation of the VAV terminal damper. Pressure transducers for VAV box flow applications do not need to have adjustable pressure ranges or integral display. Provide filter on high side of flow pickups if flow measurement device requires airflow through the device. All differential pressure transducer inputs for airflow measurement shall have a method to compensate for sensor drift to calibrate the zero point of the input. The differential pressure transducers and damper actuators can be integrated into the terminal unit controller or be discrete devices.

***Consult with the agency to determine the type of terminal unit space temperature sensors should be provided on the project. Revise the specification below if terminal unit space temperature sensors should be provided without adjustments or other special requirements, i.e. blank stainless steel plates, etc.***

Terminal unit space sensors shall be provided with digital displays with setpoint adjustments and manual occupancy override and indication of occupancy status. Provide information to the AE on sensor colors offered by the manufacturer and obtain approval on what color should be provided on the project. Provide setpoint adjustment as specified in the DDC Input/Output Summary Table and sequence of operation

Provide a method to view and print a summary of current K-factors for flow correction for each VAV terminal through the DDC system. The summary shall have a minimum of 50 K-factors per group of VAV terminals.

All system setpoints, proportional bands, control algorithms, calibration constants, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the ASC.

All application specific controllers shall be fully programmable. Question and answer or template programming is not acceptable unless this is used to generate the initial application program and the result is able to be freely modified without restriction. Control sequences for terminal unit control that utilize devices wired directly to the terminal unit application controller shall be programmed in the application specific controller and shall be stand-alone in function, i.e. occupancy sensing, temperature setpoint setback, etc. Supervisory controllers shall not be involved in the control sequence logic unless it involves sharing data between or from individual terminal unit controllers to be utilized in a global sequence, i.e. trim and respond strategies, terminal unit grouping, etc.

**OPERATOR INTERFACE REQUIREMENTS**

COMMAND ENTRY/MENU SELECTION PROCESS:

Operator interface software shall minimize operator training through the use of English language prompting and English language point identification.

TEXT-BASED DISPLAYS:

The operator interface shall provide consistent text-based displays of all system point and application data described in this specification. Point identification, engineering units, status indication, and application naming conventions shall be the same at all operator devices.

GRAPHIC-BASED DISPLAYS:

The operator interface shall provide graphic based displays of each system. The point data associated with each system shall dynamically update at a minimum of every 30 seconds. Graphic displays shall be linked to each other to provide a “drill down” capability from main graphic displays to more specific system based displays. Provide a building level graphic display that links to system graphics. For systems that have ASC controlled terminal unit controls, provide a building floor plan with dynamic temperatures shown on the graphic that can be drilled into for more specific terminal information. Points provided in the graphic shall have the override and adjust capability specified under operator commands. The contractor providing the DDC system under this Section shall provide all graphic displays for the project. Submit all graphic displays to the Agency control personnel for review and approval. Graphics shall be completed to provide enough time for approval and time for binding to be in place before control system commissioning is scheduled to occur.

PASSWORD PROTECTION:

Multiple-level password access protection shall be provided to allow the user/manager to limit control, display, and data base manipulation capabilities as he deems appropriate for each user, based upon an assigned password.

Passwords shall be exactly the same for all operator devices.

A minimum of three levels of access shall be supported:

1. Level 1: Data access and display
2. Level 2 = Level 1 + operator overrides and commands
3. Level 3 = Level 2 + database generation and modification

A minimum of 4 passwords shall be supported at each supervisory controller.

Operators will be able to perform only those commands available for their respective passwords. Menu selections displayed at any operator device shall be limited to only those items defined for the access level of the password used to log-on.

Provide user definable, automatic log-off timers of from 1 to 60 minutes to prevent operators from inadvertently leaving devices on-line.

OPERATOR COMMANDS:

The operator interface shall allow the operator to perform commands including, but not limited to, the following:

1. Start-up or shutdown selected equipment
2. Adjust setpoints
3. Override analog and binary outputs
4. Add/modify/delete time programming
5. Enable/disable process execution
6. Lock/unlock alarm reporting for each point
7. Enable/disable totalization for each point
8. Enable/disable trending
9. Enter temporary override schedules
10. Define holiday schedules
11. Change time/date
12. Enter/modify analog alarm limits
13. Enable/disable analog alarm limits
14. Enable/disable demand limiting
15. Enable/disable duty cycle

LOGS AND SUMMARIES:

Reports shall be generated manually, and directed to the displays. As a minimum, the system shall allow the user to easily obtain the following general listing of all points in the system that shall include, but not be limited to:

1. Points currently in alarm
2. Off-line points
3. Points currently in override status
4. Points in weekly schedules
5. Holiday programming

Summaries shall be provided for specific points, for a logical point group, for a user-selected group of groups, or for the entire facility without restriction due to the hardware configuration on the facility management system. Under no conditions shall the operator need to specify the address of hardware controller to obtain system information.

SYSTEM CONFIGURATION AND DEFINITION:

All temperature and equipment control strategies and energy management routines shall be definable by the operator. System definition and modification procedures shall not interfere with normal system operation and control.

The system shall be provided complete with all equipment, software, and documentation necessary to allow an operator to independently perform the following functions:

1. Add/delete/modify application specific controllers
2. Add/delete/modify points of any type, and all associated point parameters, and tuning constants
3. Add/delete/modify alarm reporting definition for each point
4. Add/delete/modify energy management applications
5. Add/delete/modify time and calendar-based programming
6. Add/delete/modify totalization for every point
7. Add/delete/modify historical data trending for every point
8. Add/delete/modify configured control processes
9. Add/delete/modify dial-up telecommunication definition
10. Add/delete/modify all operator passwords
11. Add/delete/modify alarm messages

PROGRAMMING DESCRIPTION:

Definition of operator device characteristics, ASC's, individual points, and shall be performed through fill-in-the-blank templates.

NETWORK-WIDE STRATEGY DEVELOPMENT:

Inputs and outputs for any process shall not be restricted to a single ASC, but shall be able to include data from any and all other ASC's to allow the development of network-wide control strategies.

SYSTEM DEFINITION/CONTROL SEQUENCE DOCUMENTATION:

All portions of system definition shall be self-documenting and be capable of providing hardcopy printouts of all configuration and application data.

DATA BASE SAVE/RESTORE/BACK-UP:

Backup copies of all programmable controller, ASC and supervisory controller databases shall be stored in at least one personal computer or laptop. Users shall have the ability to manually execute upload and downloading of a programmable controller, ASC and supervisory controller database.

***Determine from the Agency contact for the project which of following four operator interfaces are required. This will be for larger facilities that have onsite personnel monitoring and maintaining the building. For smaller facilities, the following Web based HTML browser interface may be more appropriate.***

**OPERATOR WORKSTATION & DDC SYSTEM SERVER**

A Personal Computer (PC) Operator Workstation and DDC System Server software shall be provided for command entry, information management, network alarm management, database management and archiving functions. The functions of the operator workstation and DDC system server may reside on a single personal computer. Provide a separate DDC System Server PC if required to perform the specified requirements. All functions specified under the entire Operator Interface section of this specification must be met.

All real-time control functions shall be resident in the stand-alone supervisory controllers to facilitate greater fault tolerance and reliability.

Workstation shall be general purpose, commercially available, personal computers with a multiple core processor with a minimum speed of 2.5 GHz, a minimum of 16GB of RAM, a minimum SSD hard drive size of 2TB. Provide more memory and/or a faster processor if necessary to perform all the functions described in this specification.

Sufficient storage shall be provided to accommodate all fully configured point databases all application databases, all graphics databases, all user-defined reports, and all historical data archived as described in this specification.

The flat panel display provided for system operation shall have a diagonal screen measurement of no less than 24" and have a minimum display resolution of no less than 1900 x 1080 pixels. Separate controls shall be provided for color, contrast, and brightness.

Provide a current production model printer.

Provide software, including but not limited to functions such as:

1. Grouping point data by systems or types
2. Displaying trends in textual and graphical format
3. Application software for programming all DDC controllers specified herein
4. Graphics definition and development
5. Managing archive data and programs

This contractor shall provide all labor and software upgrades required so that the manufacturer’s current software revision is provided for one year after the project completion date of the project as stated in the project contract documents.

Prior to installation of any Operator Workstation or DDC System server, the contractor shall work with the owner to ensure that proper virus protection software and security measures are in place before the system is put online.

Where a State agency requires the software to be loaded on a virtual machine provided by the agency, this contractor shall provide all operating system and any other database software required to run the server/workstation software. The operating system software shall meet the level and revision requirements of the Agency’s IT department even if it is a higher level than is required by the server/workstation software.

***Specify the following if a Web based HTML browser type interface is desired.***

**WEB BASED HTML BROWSER INTERFACE**

Provide a HTML based browser interface (Web Server) for accessing the DDC system. This shall include all hardware and software to provide an Ethernet twisted pair connection to the owners local or wide area network (LAN or WAN) that can be used to access the DDC system through a standard internet browser.

All information shall be provided to the owners IT staff to facilitate connection through the owners LAN/WAN.

At a minimum, this interface shall be capable of all functions described under the Operator Interface section, Password Protection, Operator Commands, and Logs and Summary subsections of this specification.

Where a State agency requires the HTML software to be loaded on a virtual machine provided by the agency, this contractor shall provide all operating system and any other database software required to run the HTML software. The operating system software shall meet the level and revision requirements of the Agency’s IT department even if it is a higher level than is required by the HTML software.

**PORTABLE OPERATOR TERMINAL**

Provide a portable interface for accessing the DDC system from a connection to a supervisory controller. This device shall, at a minimum, be capable of all functions described under the Operator Interface section, Password Protection, Operator Commands, and Logs and Summary subsections of this specification.

***Specify the following if DDC terminal units are provided and this interface is desired.***

**ASC PORTABLE SERVICE TERMINAL**

Provide a portable service terminal capable of interfacing to ASC’s through a local serial port located on the ASC or if a remote thermostat is provided for the ASC, at the thermostat. The service terminal shall be capable of displaying all input and output points, adjusting all setpoints, and all tuning parameters for the ASC.This device is primarily for setup and servicing of ASC’s.

***Specify uninterruptible power supplies for DDC controllers that serve critical systems that need to provide control of systems through a power failure are gathering information for systems where an interruption of data is not acceptable (i.e. BSL3 laboratories). Use of UPS’s should be avoided unless absolutely necessary.***

**UNINTERRUPTIBLE POWER SUPPLY (UPS)**

Manufacturers: APC (Schneider Electric) SRTxxxXLA series, Liebert (Emerson) GTX4 series, or equal.

Provide a complete uninterruptible power system as specified herein and hereafter referred to as the "UPS", to provide continuous, regulated AC power to critical loads under normal and abnormal conditions, including loss of the utility AC power to control panels that have a UPS specified in the plans and/or specifications.

The UPS shall be a double-conversion online type where the inverter shall supply AC power continuously to the critical loads. The inverter output shall be synchronized with the bypass AC power source provided that the bypass AC power source is within the specified frequency range. The rectifier/charger shall convert the normal AC input power to DC power for the inverter and for charging the battery.

Electrical Specifications: Voltage Regulation ± 3% linear load steady state; Frequency Regulation ±5% synchronized to utility / mains.; Voltage Distortion <3%; Overload rating 150%.

Sizing: The UPS shall be sized to provide a minimum of 10 minutes of backup power for the DDC panel it is specified to power at full load amps.

Loss of Normal AC Input Power: The battery shall supply DC power to the inverter so that there is no interruption of AC power to the critical loads whenever the normal AC input power source of the UPS module deviates from the specified tolerances or fails completely. The battery shall continue to supply power to the inverter for the specified protection time.

Return of Normal AC Input Power Source: The rectifier/charger shall start and assume the DC load from the battery when the normal AC input power source returns. The rectifier/charger shall then simultaneously supply the inverter with DC power and recharge the battery. This shall be an automatic function and shall cause no disturbance to the critical load.

Transfer to Bypass AC Power Source: If the control circuitry senses an overload, an inverter shutdown signal or degradation of the inverter output, then it shall automatically transfer the critical loads from the inverter output to the bypass AC power source without an interruption of power. If the bypass AC power source is above or below normal voltage limits, then the transfer shall be inhibited.

Retransfer to Inverter: The automatic bypass switch shall be capable of automatically retransferring the load back to the inverter after the inverter has returned to normal conditions. Retransfer shall not occur if the two sources are not synchronized.

Battery: Valve-regulated, non-spillable, lead acid cells (VRLA) shall be used as a stored-energy source for the specified UPS system. The battery shall be housed internal to the UPS cabinet and sized to support the inverter at rated load and power factor, with ambient temperature of 25°C (77°F) for a minimum of 10 minutes reserve time. The battery shall be hot swappable and will be able to be disconnected from the rectifier/charger and inverter. The UPS shall continue to function without the battery and meet the performance criteria specified herein except for the battery reserve time and step load performance.

Battery Monitoring: The UPS shall continuously monitor the batteries and shall be equipped with a dry contact that will indicate low battery. The normally closed contact that will open on low battery shall be wired to a digital input on a DDC controller that is being powered by the UPS and will be alarmed by the DDC system. This Section shall provide a DDC controller for monitoring of the UPS battery if there is not a digital input available on a DDC controller powered by the UPS. For dry contact only (no communication as specified below), APC dry contact option is part number AP9613 and Liebert dry contact part number is IS-Relay.

Communications: The UPS shall be capable of communicating through an integral Ethernet port or add on network card and shall provide SNMP and HTML management of the device. Provide this feature when specified in Section 23 09 93.

Mounting: For installations in mechanical or electrical rooms, mount the UPS below within the temperature control panel served or in a control panel below the temperature control panel. If located within an IT closet or room a wall mounting bracket designed for the UPS may be used. Batteries must be removable without disconnecting the power source or load from the UPS. Utilize standard 120VAC grounded plugs for connecting the load to the UPS.

**P A R T 3 - E X E C U T I O N**

**GENERAL**

All electronic work required as an integral part of the Direct Digital Control system work is the responsibility of this section unless specifically indicated otherwise in this section, Section 23 09 14, or in Division 26.

This contractor shall provide all labor, materials, engineering, software, permits, tools, checkout and certificates required to install a complete Direct Digital Control system as herein specified.

Any and all points added with this project shall be grouped for display purposes into the system such that all points associated with a new or existing DDC system can appear together on the flat panel display or printed log. Assignment of points to a group shall not be restricted by hardware configuration of the points of direct digital control. It shall be possible to assign a point to appear in more than one system. An English descriptor and an alpha/numeric identifier shall identify each system.

This Direct Digital Control system as herein specified shall be fully integrated and completely installed by this section. It shall include all required computer CPU software and hardware. Include the engineering, installation, supervision, calibration, software programming, and checkout necessary for a fully operational system.

**INSTALLATION**

All work and materials are to conform in every detail to the rules and requirements of the National Electrical Code and present manufacturing standards. All wiring and cable installation shall conform with the wiring installation as specified in the installation section of Section 23 09 14. All material shall be UL approved.

Install system and materials in accordance with manufacturer's instructions, rough-in drawings and details on drawings.

***The A/E must properly coordinate the necessary power wiring for the temperature DDC control panels with Division 26. Ensure that emergency power is supplied to DDC panels that serve equipment that is fed by emergency power.***

Line voltage wiring to power the DDC Controllers, not provided by the Division 26 contractor, to be by this contractor.

Control panels serving equipment fed by emergency power shall also be served by emergency power.

Provide uninterruptable power supplies where necessary to provide proper start-up of equipment or to accomplish power restart control sequences specified.

Mount control panels adjacent to associated equipment on vibration-free walls or free-standing angle iron supports. One cabinet may accommodate more than one system in same equipment room. Provide engraved plastic nameplates for instruments and controls inside cabinet and on cabinet face.

Provide as-built control drawings of all systems served by each local panel in a location adjacent to or inside of panel cover. Provide a protective cover or envelope for drawings.

Cable tray routing of the communication trunks is acceptable.

Where a new system is required to be extended to an existing agency Building Automation Network (BAN) (typically connected via the agency Local Area Network (LAN) or Wide Area Network (WAN)), extension of the data-net between DDC Controllers and to the BAN to be by this contractor unless specified to be provided by the division 27 contractor. All wiring and cable installation shall conform to the wiring installation as specified in the installation section of Section 23 09 14 and division 27. If division 27 is not specified in this project specifications, the state master specification 27 00 00 located on the DFD Master Specification website should be used as reference.

<https://doa.wi.gov/Pages/DoingBusiness/MasterSpecsDesignGuide.aspx>

Provide all necessary routers and or repeaters to accomplish connection to the BAN via the panel-mounted port provided.

Provide two data jacks in control panels housing supervisory controllers and allocate 6”x6” for each data jack in the panel. The first jack will be used for connecting the supervisory controller to the BAN. The second jack will be used as a spare for connecting to the BAN by service personnel.

Provide an input for a service shutdown toggle switch for each air handling unit system provided inside the temperature control panel that will initiate a logical shutdown of the air handling unit system.

All tubing, cable and individual wiring is to be permanently tagged, with numbers corresponding with "Record Drawings", spares are to be labelled as "Spare".

Provide technician to work with air balancing contractor and/or provide balancing contractor with necessary hardware to over-ride DDC controllers for air balancing.

Provide documentation to demonstrate that all points, input and output, have been checked out and verified operational, note any points not operating properly with notation of reason.

**PRECONSTRUCTION REVIEW MEETING**

This contractor shall attend a meeting or meetings as required prior to construction to review the control system on the project. The meeting attendees shall consist of the AE of Record, DFD, CxP, User Agency, Section 23 09 14 Contractor, Section 23 09 23 Contractor and the Division 23 Contractor. All sequences covered within specification section 23 09 93 and related system configurations and devices shall be reviewed in detail and any corrections to the sequences and mechanical systems shall be made through the DFD construction change process.

**CONSTRUCTION VERIFICATION**

Contractor is responsible for utilizing the construction verification checklists supplied under specification Section 23 08 00 in accordance with the procedures defined for construction verification in Section 01 91 01 or 01 91 02.

**FUNCTIONAL PERFORMANCE TESTING**

Contractor is responsible for utilizing the functional performance test forms supplied under specification Section 23 08 00 in accordance with the procedures defined for functional performance testing in Section 01 91 01 or 01 91 02.

For commissioning of control systems, the following items shall be complete by the contractor prior to functional performance testing:

* Completed functional performance tests written by the commissioning agent shall have been reviewed at the controls Preconstruction Review Meeting.
* All point to point checkout for each input/output shall be complete and documented.
* All changes to the design need to be incorporated prior to testing.
* Final user interface shall be complete. This includes all graphics, trending, and agency defined user names and grouping.

# AGENCY TRAINING

All training provided for agency shall comply with the format, general content requirements and submission guidelines specified under Section 01 91 01 or 01 91 02.

Contractor to provide factory authorized representative and/or field personnel knowledgeable with the operations, maintenance and troubleshooting of the system and/or components defined within this section for a minimum period of [XX] hours.

Provide two follow-up visits for troubleshooting and instruction, one six months after substantial completion and the other at the end of the warranty period. Length of each visit to be not less than [XX] hours or the time necessary to provide required information and complete troubleshooting and inspection activity for all controls installed under 23 09 23, 23 09 14, and 23 09 93. Coordinate the visit with the owner/Agency and provide an inspection report to the owner of any deficiencies found.

END OF SECTION