**SECTION 23 09 25**

**DIRECT DIGITAL CONTROL SYSTEM FOR HVAC**

**INTEGRATED TERMINAL UNITS**

**BASED ON DFD MASTER SPECIFICATION DATED 9/24/2019**

***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 existing facilities or campus situations where negotiated DDC controls are used and where terminal units are to be integrated to the control system that is in place. Contact the Division of Facilities Development as to whether this will be done. The AE is responsible for all design related to the DDC control system including work covered under this Section.***

***This specification is customized for use with a system that utilizes BACnet protocol specifications.***

**PART 1 ‑ GENERAL**

**SCOPE**

Work in this section includes Direct Digital Control (DDC) terminal unit application specific controllers (ASC’s), field level communication trunk, software programming, and other equipment and accessories necessary to integrate ASC’s into a supervisory controller provided under Section 23 09 24. This system interfaced with 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

 Submittal

 Operation and Maintenance Data

 Material Delivery and Storage

PART 2 - PRODUCTS

 General

 Control Panels

 Direct Digital Controls

 Networking/Communications

 BACnet Requirements

 Application Specific Controllers – Terminal Unit Control

 Communicating Thermostats

PART 3 - EXECUTION

 General

 Installation

 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

**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

ANSI/ASHRAE Standard 135-2001 BACnet - A Data Communication Protocol for Building Automation and Control Networks

**WORK NOT INCLUDED**

Section 23 09 14 and 23 09 24 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, temperature sensors, 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 warranty 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 (1979 Amendment to Part 15, Subpart J).

**SUBMITTALS**

Include the following information:

Details of construction, layout, and location of each temperature control panel within the building, including instruments location in panel and labeling. 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 startup 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. Schedules and other interface information specified below for integration of the equipment specified in this section to the ELDM shall be updated and included in the record drawings provided under this specification section. 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. 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.

The system components shall be capable of operating with 120 VAC and/or 24VAC/DC power supply and shall be fully overcurrent protected with resettable shutdown-restart circuitry. These circuits shall be implemented with the proper hardware and associated software functions. When the devices or components require 24VAC/DC, the controls contractor shall provide the proper power supplies and/or transformers. All transformers shall have resettable overload protection.

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

**CONTROL PANELS**

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.
* or 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.

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**

DDC system to consist of a supervisory controller provided under 23 09 24, stand-alone terminal unit DDC Application Specific Controllers (ASC's).

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 integration of the DDC terminal controllers provided in this section and the supervisory controller provided under Section 23 09 24 shall be capable of terminal unit equipment supervision and control, time scheduling, alarm management, energy management functions, trend data collection and reporting, and controller integrity monitoring.

Control logic necessary for DDC terminal unit control as specified in Section 23 09 15 point charts and Section 23 09 93 control sequences shall reside within the DDC terminal unit controller or the Section 23 09 24 supervisory controller.

Time schedules for occupancy and other functions specified in Section 23 09 93 shall be programmed in the 23 09 24 supervisory controller. Time schedules shall be programmed so that all terminal units served by a given AHU shall be indexed by the same schedule unless otherwise directed in the 23 09 93 sequence of operation. When specified, grouping of terminals shall be provided under this section so a single data point provided under this section associated with the grouped terminals can be scheduled in the supervisory controller.

When specified, flow totalization for AHU outside air ventilation reset shall be provided by the Section 23 09 24 supervisory controller.

When specified, static pressure reset strategies that poll the terminal units shall be provided by the Section 23 09 24 supervisory controller.

Trend data shall be collected by the 23 09 24 supervisory controller by polling the appropriate controllers provided in this section.

Alarms will be monitored by the 23 09 24 supervisory controller by polling the appropriate controllers provided in this section. Special programming shall not be required by this contractor for alarm monitoring.

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 intent of this specification is to provide a networked, stand-alone, distributed control system with the capability to integrate the ANSI/ASHRAE Standard 135-2001 BACnet communication protocols, in one open, interoperable system.

The supplied computer software shall employ object-oriented technology (OOT) for representation of all data and control devices within the system. In addition, adherence to industry standards including ANSI/ASHRAE Standard 135-2001, BACnet to assure interoperability between all system components is required. For each BACnet device, the device supplier must provide a Protocol Implementation Conformance Statement (PICS) document showing the installed device’s compliance level. Minimum compliance is Level 3; with the ability to support data read and write functionality.

The DDC terminal unit communications network shall be capable of direct connection to and communication with the supervisory controller furnished in Section 23 09 24.

Provide communication ports on all terminal unit ASC's for operator's terminal interface.

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

Global data sharing as facilitated through a 23 09 24 supervisory controller or through peer to peer communication of the ASC’s shall allow point data to be shared between 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 BACnet devices. The minimum baud rate shall be 9600 baud.
2. Support of any combination of BACnet devices. A maximum of 32 BACnet devices shall be supported on a single BACnet MSTP segment. Up to 64 BACnet devices can be connected to a single BACnet MSTP trunk.
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 BACnet MSTP protocol that utilizes IEEE RS-485 communications interface.
6. The ASC device and software object count limits shall be coordinated with the Section 23 09 24 contractor so that the required number of communication trunks are routed to the Section 23 09 24 supervisory controllers.

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**BACNET REQUIREMENTS**

Integration to the supervisory controller provided under Section 23 09 24 shall be via BACnet MSTP. Field level communications for ASC’s shall utilize BACnet MSTP - no other protocol is acceptable. All controllers to be integrated 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

For all controllers other than Communicating Thermostats that are not programmable, BACnet object name and description shall match the existing naming conventions used by the state agency for their existing Building Automation System. Coordinate with the agency and the 23 09 24 contractor to establish the naming conventions prior to programming of any controllers provided under this specification section. If the agency does not have a naming standard for a point type, the BACnet object name shall match the point description as listed in the DDC Input / Output Summary Table as listed in 23 09 15 unless the agency preference is different. All controllers, with the exception of non-programmable Communicating Thermostats, 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 these point names will be transferred through to the 23 09 24 supervisory when the auto-discovery function is executed.

A test integration of a single terminal unit controller provided under this Section shall be performed with the Section 23 09 24 contractor to ensure that the BACnet object attributes in the terminal unit controllers are correctly edited to provide the naming this is noted above will be transferred to the 23 09 24 supervisory controller during auto-discovery and will be properly presented on the Section 23 09 24 building automation system. This test integration shall be performed before this contractor programs the remaining terminal unit controllers or this contractor shall reprogram the controllers to comply with the above specification.

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.

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

**APPLICATION SPECIFIC CONTROLLERS - TERMINAL UNIT CONTROL**

Each terminal unit 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)

Provide a portable service terminal or laptop with the necessary software that can be connected to the ASC via zone temperature sensor or directly at the controller. The capabilities of the portable service terminal shall include, but not be limited to, the following information for the ASC to which connected but also any other ASC, or digital panel on the network:

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 and adjust analog setpoints
8. Modification of tuning and offset calibration constants

All temperature inputs shall have calibration offsets that can be adjusted from the portable service terminal.

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. 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.

All application software loaded in the controllers shall be provided to the agency along with all hardware (cabling, convertors, etc.) and software required to modify and download the ASC application software. If this software requires a PC to download the controllers, this contractor shall include labor to install this on an agency provided PC. Training specified under this Section shall include how to accomplish this function.

***Only allow the use of communicating thermostats for applications where a fully programmable controller is not needed and where this type of controller will be cost effective, i.e. dormitory rooms, small building furnaces, etc, and integration to a BAS is desired. These controllers are also advantages when there is limited space for a separate DDC controller to be mounted, i.e. individual radiation terminal unit control. Specify that Communicating Thermostats may be used for a given terminal unit type in the 23 09 93 sequence of operation for that terminal unit type and ensure that it has the capabilities for the sequence that is specified - these are not all fully programmable and have limitations on their functionality. Specifying that a communicating thermostat may be used should not preclude the contractor from providing an application specific controller instead. Delete the specifications below for projects where these devices are not desired.***

**COMMUNICATING THERMOSTATS**

The following thermostat(s) may be used only where specified to be allowed in the 23 09 93 specification sequence of operation for a given terminal unit type. Where not specified in the terminal unit sequence of operation and DDC control is required, an application specific controller shall be used.

Fan Coil Thermostat

Viconics model VT8300, Johnson Controls model TEC3000, Alerton VLD-362, or approved equal.

The fan coil unit DDC thermostat shall have a backlit touchscreen display that will display room temperature and provide for adjustable setpoints. The thermostat shall have the capability to be programmed locally with the setpoint parameters adjustable from the building automation system. The heating and cooling setpoint adjustments shall have the ability to be limited through the building automation system. The unit shall directly control the heating and cooling valves, and unit fan, and have two configurable binary inputs for functions such as remote night setback, service or filter alarms, motion detector and window status and have an analog input for monitoring discharge air temperature. For applications where a dehumidification sequence is specified or humidity monitoring is required, the thermostat shall have an integral humidity sensor. The thermostat shall use BACnet MSTP communication protocol and be integrated into the building DDC system. See DDC Input/Output Summary and sequence of operation for connected points and programming requirements.

Radiation Thermostat

Viconics model VT8300, Johnson Controls model TEC3000, Alerton VLD-362, or approved equal.

The radiation DDC thermostat shall have a backlit touchscreen display that will display room temperature and provide for adjustable setpoints. The thermostat shall have the capability to be programmed locally with the setpoint parameters adjustable from the building automation system. The heating setpoint adjustments shall have the ability to be limited through the building automation system. The unit shall directly control the heating valve, and have two configurable binary inputs for functions such as remote night setback, service or filter alarms, motion detector and window status and have an analog input for monitoring radiation temperature. The thermostat shall use BACnet MSTP communication protocol and be integrated into the building DDC system. See DDC Input/Output Summary and sequence of operation for connected points and programming requirements.

Staged Heating / Cooling Thermostat

Viconics model VT8600, Johnson Controls model TEC3000, Alerton VLD-362, or approved equal.

The radiation DDC thermostat shall have a backlit touchscreen display that will display room temperature and provide for adjustable setpoints. The thermostat shall have the capability to be programmed locally with the setpoint parameters adjustable from the building automation system. The heating and cooling setpoint adjustments shall have the ability to be limited through the building automation system. The unit shall directly control the heating and cooling staged outputs, and have two configurable binary inputs for functions such as remote night setback, service or filter alarms, motion detector and window status and have an analog input for monitoring discharge temperature. The unit shall be capable of modulated economizer damper control and shall have an auxiliary binary output that can be programmed for controlling a minimum outside air damper when indexed to occupied mode. The thermostat shall use BACnet MSTP communication protocol and be integrated into the building DDC system. See DDC Input/Output Summary and sequence of operation for connected points and programming requirements.

Heat Pump Thermostat

Viconics model VT8600, Johnson Controls model TEC3000, Alerton VLD-362, or approved equal.

The heat pump DDC thermostat shall have a backlit touchscreen display that will display room temperature and provide for adjustable setpoints. The thermostat shall have the capability to be programmed locally with the setpoint parameters adjustable from the building automation system. The heating and cooling setpoint adjustments shall have the ability to be limited through the building automation system. The unit shall directly control the heating and cooling stages, reversing valve, and unit fan, and have two configurable binary inputs for functions such as remote night setback, service or filter alarms, motion detector and window status and have an analog input for monitoring discharge air temperature. The thermostat shall use BACnet MSTP communication protocol and be integrated into the building DDC system. See DDC Input/Output Summary and sequence of operation for connected points and programming requirements.

Multiple Terminal Thermostat

Viconics model VT8000, Johnson Controls model TEC3000, Alerton VLD-362, or approved equal.

The DDC thermostat shall have a backlit touchscreen display that will display room temperature and provide for adjustable setpoints. The thermostat shall have the capability to be programmed locally with the setpoint parameters adjustable from the building automation system. The heating and cooling setpoint adjustments shall have the ability to be limited through the building automation system. The unit shall directly control the heating and cooling terminal units through the type of outputs as specified in 23 09 15. The unit shall have two configurable binary inputs for functions such as remote night setback, service or filter alarms, motion detector and window status and have an analog input for monitoring an additional temperature. If the application requires an analog output for heating or cooling and binary output(s) for heating or cooling and the thermostat does not support both analog and binary outputs, provide an analog to binary device capable of converting an analog output signal to binary outputs. This device shall have adjustable input thresholds for setting the trip level for each binary output and adjustable deadbands to prevent load over-cycling. The thermostat shall use BACnet MSTP communication protocol and be integrated into the building DDC system. See DDC Input/Output Summary and sequence of operation for connected points and programming requirements.

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

**GENERAL**

All electronic work required as part of the Direct Digital Control system work for DDC terminal unit control is the responsibility of this section unless specifically indicated otherwise in this section, Section 23 09 24, Section 23 09 14, 23 09 15, 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 terminal unit system as herein specified.

This Direct Digital Control system as herein specified shall be fully integrated with the 23 09 24 supervisory controller and completely installed by this section. 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 material shall be UL approved.

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

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

Mount control panels adjacent to associated equipment on vibration-free walls or freestanding angle iron supports. One cabinet may accommodate power for multiple terminal unit controllers. Provide engraved plastic nameplates for instruments and controls inside cabinet and on cabinet face.

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

The portable service terminal shall be utilised by the balancing contractor to set all the necessary parameters necessary for accurate airflow control of the DDC terminal unit. Provide necessary training to the balancing contractor so he can perform this function without assistance.

Provide all BACnet MSTP communication wiring to the supervisory controllers provided under Section 23 09 24 in the locations shown on the plans. Coordinate with the 23 09 24 for determining device limits and trunk routing to supervisory controllers.

Provide technician to work with 23 09 24 contractor to coordinate connection of terminal unit DDC system to the supervisory controller furnished by the 23 09 24 contractor.

This contractor shall be responsible for coordination with the mechanical contractor and providing for all valves that are controlled by the terminal unit controllers provided under this section to be overridden open for system cleaning of water piping.

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.

**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.

**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 this section. Coordinate the visit with the owner/Agency and provide an inspection report to the owner of any deficiencies found.

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