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

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 REFERENCE STANDARDS

A. Work under this Section is subject to requirements of Contract Documents including General Conditions, Supplementary Conditions, and sections under Division 01 General Requirements.

B. ASHRAE Standard 135 – 2016: BACnet® – A Data Communication Protocol for Building Automation and Control Networks

C. UL 916 – Energy Management Equipment

D. NFPA 70 –National Electric Code (2017)

1.3 DEFINITIONS

A. ASC: Application Specific Controller. A networked device or node that contains a complete, configurable application that is specific to a particular task.

B. Alarms & Events: The exchange of data between devices related to the occurrence of a predefined condition that meets specific criteria (event).

C. BC: Building Controller. Provide supervisory control, scheduling, trend logging, optimizations, & alarm handling.

D. B-OWS: BACnet Operator Workstation.

E. B-BC: BACnet Building Controller. Same as SLC.

F. B-AAC: BACnet Advanced Application Controller. Same as PPC.

G. B-ASC: BACnet Application Specific Controller.

H. B-SA: BACnet Smart Actuator.

I. B-SS: BACnet Smart Sensor.

J. BBMD: BACnet Broadcast Management Device.

K. BIBBS: BACnet Interoperability Building Blocks. Specific individual function blocks for data exchange between interoperable devices.

L. Broadcasting: The propagation of data from a device to the control network. Software objects that broadcast data to the network may include the following parameters:
   1. Send on Delta: An adjustable parameter that defines a requirement to broadcast when the data generated by the software object changes by an amount that exceeds this parameter's value. For binary data, this parameter defaults to a change of state. The broadcast of data is initiated when this criterion and the minimum send time requirement have been met. Also referred to as a "Change of Value".
   2. Minimum Send Time: An adjustable parameter that defines a mandatory time period during which no broadcasting of data will occur. Once this time period has been exceeded without a broadcast, the send on delta parameter or the maximum send time parameter shall determine when a broadcast is initiated.
   3. Maximum Send Time: An adjustable parameter that defines the maximum time period between broadcasts of a software object's data to the network. Should the value of a software object remain constant over an extended period of time, the value will be rebroadcast once every maximum time period.

M. BTL: BACnet Testing Laboratory.

N. Channel: One or more segments not containing a router.

O. Domain: A logical collection of devices on one or more channels.

P. FLN: Floor Level Network. BACnet IP

Q. HMI: Human-Machine Interface. Graphical operator BAS interface. Same as Graphical User Interface (GUI).

R. LAN: Local Area Network. Same as Floor Level Network.

S. Maximum Event Time: Event driven communication parameter specifying the time period for which data must not be sent more than once.

T. PICS: Protocol Implementation Conformance Statement. Detailed description for a given BACnet device stating its inherent BACnet capabilities.

U. Point: Group of data, which corresponds to a hardware input, output, or calculated value.

V. PPC: Programmable Process Controller. Same as Advanced Application Controller (AAC).

W. Scheduling: The exchange of data between devices related to the establishment and maintenance of dates and times at which specified output actions are to be taken.

X. Send on Event: Event driven communication parameter specifying the amount of variable change before data is to be sent between the Minimum and Maximum send times.

Y. SLC: Supervisory Level Controller. Same as Building Controller.

Z. Segment: A section of uninterrupted cable where multiple devices may be installed.

AA. Subnet: Logical division of a domain.

BB. Trending: The accumulation of (time, value) pairs at specified rates for a specified period duration.

1.4 SYSTEM DESCRIPTION

A. Overview

There are two major aspects to the BAS architecture at DFW Airport: BAS and EIOS. The BAS aspect is the use of traditional Building Automation Systems to accumulate data and perform as the programming and configuration tool for the field devices. While traditional BAS systems provide operational graphics, trending capabilities and alarm management, the BAS systems at DFW Airport are migrating to a format where these duties are relegated to the EIOS system leaving the BAS to be dedicated to control system operation. As such, the EIOS system is configured to integrate various HVAC, Lighting and other control systems into a common presentation and use platform, allowing for consistency for the user and a focused resource for integrated tools.

B. Enterprise Level Systems Architecture

1. The EIOS platform will be considered the general access point to any building automation aspect and the primary source for data analysis. There is a desire to have a limited number of BAS systems in use at the Airport to maximize our ability to support and operate the systems effectively. Information from facilities will be sent to both its respective BAS for operations, and to EIOS for presentation and analysis. Key points of difference include:
    a. EIOS will be used by Airport management and Quality Control for situational awareness and performance qualifications. EIOS will also be used by contracted HVAC maintenance for evaluation and troubleshooting of the HVAC equipment.
    b. EIOS will be used for horizontal integration of traditional BAS systems and vertical integration to other business systems (CMMS, Analytics, Micro Strategies, etc.).
    c. On occasion, EIOS will be responsible for unique data collection as is the case with monitoring the main electrical switchgear equipment. For the typical installation, minor systems using BACNet gateways will be integrated to the BAS assigned to that facility.
    d. The BAS system (this contract) will serve as the system administration tools for the programming, configuration, and building-level data exchange.
    e. Data points will be duplicated in EIOS and mapped as appropriate from the host BAS.
    f. All servers are virtualized in the DFW Airport IT Network. New installations will use one of the existing servers. All installations will be treated as the expansion of an existing system.
    g. In special system applications, such as Dynamic Glass and exterior Lighting Controls, using off-premises or Cloud-based systems are not encouraged but can be considered.
2. New installations will use a selected provider of system that can be programmed by approved programming tools:
    a. Johnson Controls – CCT or Metasys
    b. Schneider Electric – Work Place Tech or Workbench
    c. Distech – Eclypse

3. Building and field level controllers must natively integrate to the BAS front-end system selected for the facility.
4. Once configured in the BAS system, building level controllers (JACEs) will be mapped to the EIOS system by the EIOS Administrator. The BAS contractor will support the EIOS Administrator's mapping efforts.
5. Any integration devices must be included as part of the contractor's package.
6. The proposed system must stand on its own and not rely on any external JACE or devices except for IP networking and the front-end resource.
7. The vendor will ensure that the airport is provided with all tools, licenses, administrative passwords, and software necessary to program all installed devices.
8. ALL devices will be fully open BACnet. No proprietary licenses will be allowed.
    a. Non-Schneider Electric JACEs will communicate using BACNet protocol.
    b. Schneider Electric JACEs can communicate to Niagara and EIOS using FOX protocol.
9. Graphics shall be created to operate in EIOS environment. The graphics can be initially created in the host BAS then migrated to the EIOS server. Virtual migration is allowable if changes to either graphic will replicate in the other system.
10. Graphics must use the same template used for identical equipment already in EIOS.
11. New graphics must be created to accurately represent the features of equipment units which do not conform to existing graphics. These new graphics must follow the same mindset of existing graphics for similar equipment.

C. Points Management
1. Building Analytics
    a. Points must be integrated to the EIOS Building Analytics tool. This will include identification of all points and mapping to the tool.
2. Alarms
    a. Alarming will be managed by the EIOS system.
    b. There will be three categories of alarms recognized by EIOS: Info, Minor, and Major. Info alarms will consist of conditions that may warrant human intervention. These will be presented on a reactive screen or report. Minor alarms will consist of operational deficiencies that need attention in a timely manner. Typically, these will be sent automatically to INFOR to generate a Work Order. An alarm will be considered "Major" when it requires immediate awareness and attention by MEPS and management.
    c. EIOS will manage transmission of Minor and Major alarms to INFOR.
    d. EIOS will manage notifications to email lists (including email-to-text addresses) based on preconfigured distribution lists.
3. Trends
    a. All hard BAS points and BAS set-points shall be available to EIOS for trending. Including:
        1) Airflow (CFM)
        2) CO2 Level
        3) Damper Positions
        4) Differential Pressures
        5) Equipment Status
        6) Pressures
        7) Temperatures
        8) Valve Positions
        9) VFD kW
        10) VFD Hz
        11) VFD Percent Speed

b. Trend reports must be able to include data within the most recent 15-minute period.

D. Access Configuration
1. The configuration of the user credentials must be assignable to allow only selected users access to the information for the site.
2. Read/write capabilities must be assignable.
3. All components in the project must be in two unique categories. These must be configured to allow a user to see one, the other, both or neither.
a. Components in the Terminal F, Phase 1 footprint
b. Components in the Terminal D footprint

E. Controls lines of demarcation
1. Physical
a. BAS Contractor will be responsible for installation and configuration of all control devices downstream of the connection to the network. This includes controllers, routers, and the cabinets in which they are installed. This also includes installation of conduits as necessary and all materials for MSTP trunks.
b. Cat 6 connection points will be provided by others (TBD: DFW IT, project electrical contractor, project communications contractor, etc.) and will extend from the nearest DFW IT comm room patch panel to the location of the networked device (JACE, IP-based field controller, BACnet router, etc.)
c. DFW IT will be responsible for connecting the patch panel to the network switch and configuring the port as appropriate.
2. Integration to CMMS
a. Controlled devices will need to be assigned in the Airport's CMMS to provide automated Work Order generation. Assignment will require naming consistency between the two systems.
3. BAS Contractor vs EIOS Administrator
a. The BAS Contractor will be responsible for all aspects of installation of the field devices and configuring the BAS system (Niagara, Metasys, etc.) to digest all relevant points. They will also implement all programming of building- and field-level controllers.
b. The EIOS Integrator will be responsible for representing all available points in the EIOS system. This includes:
1) Configuring graphics (either template or new)
2) Trends
3) Alarms
4) User access configurations
5) Mapping to CMMS
6) Mapping and assignments to Building Analytic

F. Niagara Framework
1. The BAS Control System as provided in this Division shall be "Open Licensed" and based on the Niagara 4 Framework (or "Niagara"), a HTML-based framework developed by Tridium. Niagara provides an open automation infrastructure that integrates diverse systems and devices (regardless of manufacturer, communication standard or software) into a unified platform that can be easily managed in real time over the Internet using a standard Web browser. Systems not developed on the Niagara 4 Framework platform are unacceptable.

1.5 SUBMITTALS

A. Shop Drawings:
1. Submit shop drawings for each hardware device used and submit complete description of software applications used. Submit manufacturer's printed product data sheets for each device or software program used. Datasheets shall be submitted electronically in pdf format with bookmarks provided for each individual device and table of contents listing each device manufacturer and full model number with links to device pages. Organize sheets in order of model number, alphabetically, then numerically. When a manufacturer's data sheet refers to a series of devices rather than a specific model, the data specifically applicable to the project shall be highlighted or clearly indicated by other means.
2. Submittals shall include points list of each control input and output, controlled devices, locations of devices, and symbol or label of each control point in software.
3. BACnet Testing Laboratory (BTL) Certificates of Compliance for all hardware used.

B. Operating and Maintenance Manuals: Refer to Section 23 0901 - Control System Integration.

C. Software Manual:
1. As part of operating and maintenance manuals, submit one software manual plus one extra copy for archive use. Software manuals shall be divided into separate parts with tabs for each part.
2. Software manual parts shall include:
   a. Complete description of operating system including all commands, configuration programs, printouts, logs, database functions and passwords. Describe general operating procedures, starting with system overview and proceeding to detailed description of each software command feature with sample printed displays and system function description for each option. Include instructions on verifying errors, status, changing passwords and initiating or disabling control programs.
   b. Complete description of programming language including all commands, configuration programs, control loop functions and testing. Describe general programming procedures, starting with system overview and proceeding to detailed description of each software command feature. Include instructions on creating or modifying any control algorithm or parameter, debugging, etc. This shall include all control functions, algorithms, mathematic equations, variables, setpoints, time periods, messages, and other information necessary to load, alter, test, and execute custom or pre-written programs.
   c. Software Backup: Upon successful completion of acceptance testing, submit to Owner 2 archive copies of all accepted versions of source code and compiled code for all application programs and data files on CD ROM backup disks. All control software must be readily accessible by Owner using BAS workstation hardware and software.
   d. Web server/data historian SQL database schema (table format) for trend data and event/alarm data.
   e. BAS Points List Summary: Provide detailed summary for each point in the system. Summary shall be cross-index listing of all points in alpha/numerical order with list of control loops which use each point. For each point, include an abbreviated point name, expanded point description, detailed description of each input instrument or output device, and detailed description of exact location of all field hardware. Location descriptions shall include room names, column numbers, elevation (above ceiling, bottom of duct, etc.).

1.6 WARRANTY

A. Provide 2-year warranty on all materials and labor.

B. Warranty requirements shall include furnishing and installing software upgrades issued by the manufacturer during the 2-year warranty period.

1.7 FCC COMPLIANCE

A. Digital equipment furnished under this contract shall be tested and made to comply with limits for Class A computing devices pursuant to Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against interference when operated in commercial environments. Literature shall so note and equipment shall be so labeled to show this compliance.

1.8 BACNET COMPLIANCE

A. All hardware shall be BTL listed and compliant.

B. At minimum, the following BACnet Building Interoperability Blocks shall be met:

Data Sharing	Alarm & Event	Scheduling	Trending	Device & Network Mgmt.
DS-RP-A,B	AE-N-A	SCH-I-B	T-VM-I-B	DM-DDB-A,B
DS-RPM-A,B	AE-N-I-B	SCH-E-B	T-VM-E-B	DM-DOB-A,B
DS-WP-A,B	AE-N-E-B		T-ATR-B	DM-DCC-B
DS-WPM-B	AE-ACK-B			DM-TS-A,B
DS-COVU-A,B	AE-ASUM-B			DM-UTC-A,B
	AE-ESUM-B			DM-ATS-A
				DM-RD-B
	AE-INFO-B			DM-BR-B
				DM-R-B
				DM-OCD-B
				NM-CE-A

1.9 BMS ARCHITECTURE

A. All networked control products provided for this project shall be comprised of an industry standard open protocol internetwork. Communication involving control components (i.e., all types of controllers and operator interfaces) shall conform to ASHRAE 135-2010 BACnet standard. Networks and protocols proprietary to one company or distributed by one company are prohibited.

B. Access to system data shall not be restricted by the hardware configuration of the building management system. The hardware configuration of the BMS network shall be totally transparent to the user when accessing data or developing control programs.
   1. Software applications, features, and functionality, including administrative configurations, shall not be separated into several network control engines working together.

2. All physical points, network integration points, and logic points in each controller shall be mapped to the system server database whether explicitly requested on the point list or not. The intent is to make all data readily accessible in future renovations.
3. Data visibility shall not be limited to the minimum requirements set forth by ASHRAE/ANSI Standard 135.

C. The owner will provide a Graphics Server, and contractor shall install Tridium Niagara 4 server application software. The BMS server Additional operator interfaces shall use operator workstation licenses or connect via a thin-client application.

D. The Tridium Server shall be capable of simultaneous direct connection and communication with BACnet/IP, Modbus TCP/IP, and TCP/IP corporate level networks without the use of interposing devices.

E. Any break in Ethernet communication from the PC to the controllers on the Primary Network shall result in a notification at the PC.

F. Any break in Ethernet communication between the standard client and server workstations on the Primary Network shall result in a notification at each workstation.

G. The network architecture shall consist of three levels of networks:
1. The Management level shall pass information across the Niagara Network. It shall network the BMS Server, Operator workstations, and Tridium Niagara 4 “Open Licensed” BC level controllers.
2. The Automation level network shall be BACnet/IP over Ethernet. It shall network the AHU, meters, and Plant type controllers that communicate BACnet/IP. These points shall be integrated into the BC level controllers.
3. The Floor level network shall be BACnet over MS/TP. It shall network to all the DDC controlled equipment on a floor or in a system. All points shall be integrated up to the BC level controllers.

H. The primary backbone network between the building level controllers, BMS Server, and Operator Workstations shall be based upon the Niagara Network. Ethernet Network switches shall be strategically placed through the building to cover several floors or several mechanical rooms that are within 300 ft. wiring-feet of each other. Note that the 300-foot requirement refers to length of cable run, and not plan view distances.

I. The Building Level Controllers shall be able to support subnetwork protocols that may be needed depending on the type of equipment or application. Subnetworks shall be limited to BACnet, unless otherwise approved by owner.

J. Application specific controllers for smaller single zone, supplemental or special systems can reside on the BACnet/IP network or on a subnetwork.

K. Floor level controllers, terminal units, package AC units, auxiliary equipment, VFDs, meters shall reside on one of the subnetworks above.

L. Controllers and software shall be BTL listed at the time of installation.

M. The system shall meet peer-to-peer communication services such that the values in any one BC or AAC level controller can be read or changed from all other controllers with the need for intermediary devices. The software shall provide transparent transfer of all data, control

programs, schedules, trends, and alarms from any one controller through the internetwork to any other controller, regardless of subnetwork routers.

N. Systems that use variations of BACnet using Point-to-Point (PTP) between controllers, gateways, bridges, or networks that are not peer-to-peer are not allowed.

O. Where a smoke control application is required, provide UUKL listed network switches, and NFPA approved cabling, enclosures, and installation methods.

P. The system shall be installed with a 10% spare capacity on each subnetwork for the addition of future controllers.

PART 2 - PRODUCTS

A. General:
1. DDC controllers shall be microprocessor based, field programmable controllers, capable of performing control and energy management functions, and shall be UL listed as Signaling Systems. Each controller shall include its own microprocessor, power supply, input/output modules, and termination modules as required to perform intended function.
2. DDC controller shall receive discrete electrical and/or analog electronic field input signals, convert signals for use by controller, perform control sequences, convert controller information into output signals, and provide control output signals to actuators and field control devices. Inputs and outputs, including communication connections, shall be electrically or optically isolated from controllers.
3. All DDC controllers shall be provided by the same manufacturer.
4. DDC controller with analog input modules shall be capable of accepting any form of linear or non-linear voltage (0-5 VDC or 0-10 VDC), current (4-20 mA) or resistive input (0-1000 ohm).
5. DDC controller with discrete input modules shall be capable of accepting discrete inputs from any device with isolated, dry-type contacts (no grounds or no voltage) of either normally open (NO) or normally closed (NC) configuration. Provide visible status lights (LEDs) to indicate input point status.
6. Provide input modules capable of interfacing with pulsed output type sensors as required.
7. DDC controller with discrete output modules shall have isolated, dry-type contacts (no grounds or no voltage) of either normally open (NO) or normally closed (NC) configuration. Provide visible status lights (LEDs) to indicate output point status.
8. DDC controller shall have capability to scale, offset, and display proper analog value without field hardware modification. DDC controller shall convert analog input signals to digital values (A/D conversion) and convert digital values to analog outputs (D/A conversion) for modulating control purposes. Some application specific controllers may utilize tri-state or Triac outputs for floating point control of control devices. Floating point control should be limited to non-critical room temperature control and mechanical space heating and cooling.
9. Failsafe hardware shall be provided such that BAS failures result in immediate return to local control. If DDC controller uses database values from other DDC controllers and communication network fails or malfunctions, control loop outputs shall continue to function using last value received from BAS.
10. Failure of network or control devices (i.e., building level controllers, floor level controllers, application specific controllers, routers, repeaters, etc.) shall be alarmed at the Operator Workstation as a Level 3 Critical Alarm.
11. All DDC Hardware shall meet the following requirements:

a. All DDC controllers shall be connected to an ASHRAE 135 MS/TP, BACnet or BACnet/IP control network and communicate via ASHRAE 135 exclusively.
b. MS/TP controllers shall operate at 76.8 kbps, and a minimum baud rate of 38.4 kbps.
c. All DDCP shall implement all required functionality of the application network interface via BACnet objects, properties, and services.
d. All DDC controllers shall conform to the BACnet Testing Lab's Device Implementation Guidelines and be BTL Listed.
e. Application programs and configuration settings shall be stored in a manner such that a loss of power does not result in a loss of the application program or configuration settings.
f. All settings and parameters used by the application shall be fully configurable to the greatest extent possible, via properties of BACnet objects that can be written to via BACnet services or via properties of BACnet objects that can be written to via BACnet services for the following:
    1) Setpoint
    2) Alarm limit
    3) Schedule modification
    4) Trend modification
g. All other settings and parameters that cannot be written to via BACnet services shall be fully configurable via either properties of BACnet objects that can be written to with a configuration tool, or via hardware settings on the controller itself to support the application.

12. Each DDC panel shall have sufficient I/O capacity to perform specified control sequences and/or include points listed in point schedules. If DDC controller does not have sufficient capacity, provide additional slave I/O panels to achieve required point count.
    a. A minimum of 10 percent additional hardware (field) points with the addition of field devices/hardware.
    b. A minimum of 10 percent additional system graphics diagrams and point programming in addition to those required to meet these specifications.
13. Analog and critical safety discrete control loops shall have inputs and outputs into/from same DDC panel. Analog control loops for major equipment (chilled water, hot water, convertors, air handling units, etc.) shall have PID control.

B. BACnet Building Controller (B-BC):
1. BACnet Building Controllers (B-BCs) shall be “Open Licensed” Tridium Niagara 4, and provide direct connection to high speed, BACnet/IP Local Area Network (LAN) and Campus Ethernet network and serve as communications router for other controllers on slower speed BACnet MS/TP or BACnet over ARCNET Floor Level Network (FLN).
2. Communication between B-BCs shall be through the Niagara Network.
3. The number of B-BCs required is dependent on the type and quantity of BACnet MS/TP devices. It is the responsibility of the controls contractor to determine how many B-BCs are required to meet expansion requirements and provide a stable system that is within manufacturer recommended memory/resource utilization.
4. B-BCs shall have sufficient processor capabilities, hard-drive storage and RAM to implement all types of custom software applications and shall provide supervisory control, scheduling, trend logging & alarm handling functions as follows:
    a. Scheduling:
        1) Each B-BC shall support a minimum of 250 BACnet Schedule Objects and 250 BACnet Calendar Objects.
    b. Trending:

1) Any object in the system (real or calculated) may be logged. Sample time interval shall be adjustable at the operator's workstation.
2) B-BC shall periodically upload trended data to networked BAS Web Application Server for long term archiving.
3) Archived data shall be stored in standard database format and shall be made available for use in third-party spreadsheet or database programs.

c. Alarm Generation:
1) Alarms may be generated within the system for any object change of value or state either real or calculated. This includes analog object value changes, binary object state changes, and various controller communication failures.
2) B-BC shall periodically upload alarm logs to networked BAS Web Application Server for long term archiving.

5. B-BCs shall have uninterrupted real time clocks capable of time of day, week, and year information to the system as needed to perform software functions. Clock shall be programmed to reset twice per year to allow for Daylight Savings Time. Clocks in multiple DDC Controllers shall be synchronized to automatically match designated B-BC's or Web server. Accuracy shall be within 1 second per day.
6. Batteries shall maintain volatile memory and real time clocks for a period of at least 72 hours during power failure. Batteries shall be maintenance free and have minimum life of 2 years. When power has been restored, the following shall occur automatically:
a. Orderly startup of controlled equipment (user defined)
b. Continuation of control algorithms
c. Database revision
d. Logging of power interruption and restoration times
e. Battery recharging
7. Provide local visual indication and system annunciation of low battery power for each battery.
8. Each B-BC shall include its own micro-processor, power supply, input/output modules, and termination modules as required to perform intended function.
9. BACnet UDP port number to always be set to 47808 (BAC0).

C. BACnet Advanced Application Controllers (B-AAC):
1. B-AACs are defined as having sufficient processor capabilities and RAM to implement all types of custom software applications.
2. B-AACs shall be capable of communicating to BAS network via BACnet MS/TP connected to Building Controller or via BACnet/IP directly.
3. All B-AACs controlling major mechanical equipment/systems and lab equipment monitoring shall communicate via BACnet/IP as indicated on BAS Network Architecture drawings.
4. Provide at least one extra communication port at each B-AAC for direct connecting a notebook computer or hand-held terminal.

D. BACnet Application Specific Controllers (B-ASC):
1. B-ASCs are defined as having standard software burned into EPROM, set points in EEPROM or RAM maintained by battery, and are designed to handle specific types of control sequences.
2. Application specific DDC Controller shall be capable of communicating to BAS network via low/medium speed network connected to B-BC.
3. Control outputs may be in the form of floating-point control or true analog output control of end devices. Floating point control shall be limited to non-critical room temperature control or mechanical space heating and cooling.

4. Provide communication ports integral room temperature sensors/thermostats for interface with local terminal equipment controllers or a low range wireless (Bluetooth®) Commissioning tool that provides a temporary wireless connection between the MS/TP network and the laptop computer used to commission.

E. BACnet Gateways:
1. All controllers installed shall be BACnet; if BACnet is not available, the owner shall be notified. Gateways are only allowed with the owner approval.
2. Provide gateways to connect BACnet to non-BACnet devices, and non-BACnet DDC controlled equipment.
3. Provide with each gateway an interoperability schedule, showing each point or event on the non-BACnet side that the BACnet "client" will read, and each parameter that the BACnet network will write to. Describe this interoperability in terms of BACnet services, or Interoperability Building Blocks (BIBBS), defined in ASHRAE 135 Annex K. Provide two-year minimum warranty for each gateway, including parts and labor.
4. The following minimum capabilities are required:
   a. Gateways shall be able to read and view all readable object properties listed in the interoperability schedule on the non-BACnet network to the BACnet network and vice versa where applicable.
   b. Gateways shall be able to write to all writeable object properties listed in the interoperability schedule on the non-BACnet network from the BACnet network and vice versa where applicable.
   c. Gateways shall provide single-pass (only one protocol to BACnet without intermediary protocols) translation from the non-BACnet protocol to BACnet and vice versa.
   d. Gateways shall meet the requirements of Data Sharing Read Property (DS-RP-B), Data Sharing Write Property (DS-WP-B), Device Management Dynamic Device Binding-B (DM-DDB-B), and Device Management Communication Control (DM-DCC-B) BIBBs, in accordance with ASHRAE 135.
   e. Gateways shall include all hardware, software, software licenses, and configuration tools for operator-to-gateway communications. Provide backup programming and parameters on CD media and the ability to modify, download, backup, and restore gateway configuration.

F. Power Supplies:
1. Power supplies shall operate on nominal 120 V, 60 Hz, single-phase power. DDC Controllers shall be provided with surge and noise protection. Power fluctuation shall not affect control system. Include surge protection on telephone line.
   a. Isolation transformers shall be included when connections are being made between 2 separate buildings.

2.2 DIRECT DIGITAL CONTROL SOFTWARE

A. General:
1. Software functions and algorithms shall be sufficient to enable implementation of control sequences as specified and shall be able to maintain continuous control as intended.
2. Control functions shall include both mathematical and logical operators. Control algorithms shall include proportional, integral, and derivative control (PID). Adaptive (self-tuning) PID loop parameters, if offered by DDC Controller manufacturer, shall not be used unless adaptive limits are used to adjust limit values based on system status; or written request is submitted and approved by Engineer.

3. Allow operators to assign unique identifiers of their choice to each connected point. Identifiers shall have at least 8 alpha/numeric characters. References to these points in programs, reports and command messages shall be by these identifiers.
4. Provide access control (user defined passwords) for system operation. There shall be minimum of 3 access levels. First level shall allow system monitoring only. Second level shall allow monitoring, set point adjustment, and scheduling revision. Third level shall allow modification of control algorithms. System shall return to secured (monitoring only) mode after 5 minutes of inactive operation.
5. Each DDC Controller shall contain self-diagnostics that continuously monitor proper operation of panel.
6. If microprocessor malfunctions, control loop outputs shall continue to function using last value received from microprocessor.

B. Building Controller Software:
1. Provide DDC Controller software application program modules for performing energy management control functions such as time of day change of database values (programmed start/stop, temperature setbacks, etc.), supply air temperature reset based on space load demand, economizer control, optimum start/stop based on current indoor and outdoor psychometrics, duty cycling and client tailored programs required for special applications such as VAV fan matching and supply fan control, enthalpy control, intermediate season or "dead band" control, totalizing, and holiday programming.
2. Provide manufacturer's standard operating system for real time control of system interactions, including database information requests/transfers by system hardware or by operators. Operating system shall also have the following additional capabilities (given that operator has appropriate security access level):
    a. User interface and online system configuration software embedded in Building Controller.
    b. Support for Web services at the automation network level.
    c. Displaying database (point) value including measured values, controlled variables, setpoints, gain factors, and any other adjustable parameters.
    d. Changing or overriding any database value.
    e. Error detection, correction, re-transmission of database values, arithmetic, or logical faults.
    f. Alarm reporting including sending alarms to remote workstations, User Interface Web Server, or Data Historian on network.
    g. Alarm buffer to retain alarms in order of importance without losing any alarms.
    h. Creating and displaying historical trend logging of any value, limited only by available memory.
    i. Creating new variable database values (soft points) based on arithmetic calculation (including summation or totalizing) on other database values.
    j. Adding new hardware points without overall BAS shutdown.

C. B-ASC Controller Software:
1. Manufacturer's standard software for B-ASC's may be used only if control sequences can be implemented without modification. If control sequence cannot be accomplished with standard software, provide battery backed RAM or EEPROM DDC Controller (B-AAC) capable of being programmed for specified control sequence.
2. Provide software for portable PC units to communicate with terminal controllers at the room level network. Software shall allow access to modify, delete, or create control strategies at the room sensor location.

2.3 OPERATOR'S WORKSTATION - HARDWARE

A. None. Refer to EIOS.

2.4 ENGINEERING WORKSTATION

A. None. Refer to EIOS.

2.5 WEB APPLICATION SERVER

A. Refer to 25 0924 – Graphical user Interface Integration.

2.6 DDC ENGINEERING (PROGRAMMING) – SOFTWARE

A. Provide engineering software for all Engineering Workstations and laptops.

B. Software shall have the same characteristic and capabilities as DDC Controllers. In addition, operator's workstations shall have the following features.

C. User Programmability:
   1. Engineering workstation software shall include field-engineering tools (software & hardware) for programming all controllers supplied.
   2. All application software shall be interactive, fully prompted, and menu driven and shall provide the following functionality as a minimum:
      a. Determine control strategies, which have been defined for specific piece of equipment.
      b. Add control loops to system using English language type program language qual to BASIC or other easily learned language or function block programming. (PASCAL, C, or other assembly type languages are not acceptable.)
      c. Add points to system.
      d. Create, modify, or delete control strategies.
      e. Create, modify, or delete system graphics.
      f. Assign sensors and/or actuators to control strategy.
      g. Tune control loops through adjustment of control loop parameters.
      h. Enable or disable control strategies.
      i. Generate hard copy records of control strategies on printer or soft copies to files compatible with Microsoft Office applications.
      j. Select points to be alarmable and define alarm state(s).
      k. Select points to be trended over a period of time and initiate recording of values.
      l. Override Input/Output points for each individual controller.

2.7 OPERATOR WORKSTATION – SOFTWARE

A. Custom Database Functions:
   1. Operator shall be capable of generating long term historical trend logs and displaying information in tabular or graphic formats. Provide all software options for standard and custom report generators.

B. Color Graphics:
   1. Provide color graphics software package compatible with manufacturer's standard software. Provide mouse or other special hardware required to operate software. Software shall be capable of user editing of text fields, graphics, alarms, and real-time variables.
   2. Software shall be capable of importing files in AutoCAD format, directly or via translators.

2.8 NETWORK HARDWARE

A. Provide network interface hardware for each device connected to network. Each device shall have sufficient performance as not to degrade specified processing speed.

B. Provide network cabling with sufficient performance as not to degrade specified communication speed. Cabling shall be compatible with proposed system and shall comply with requirements specified in Section 23 0901 - Control Systems Integration.

C. Provide other network support devices that are required for proper operation of network, such as file servers, signal repeaters, network hubs, etc.

D. Provide network diagnostic tool for measuring/confirming bandwidth usage on IP layer.

PART 3 - EXECUTION

3.1 GENERAL

A. Install control equipment in neat, professional manner to satisfaction of Architect and Engineer.

B. Coordinate timely delivery of materials and supervise installation of DDC Controllers and network cabling and devices.

C. Install DDC Controllers and network control devices in accessible locations.

3.2 OVERALL BAS ARCHITECTURE

A. Provide hardware/software to update database in less than 1 second for fast-acting control loops such as pressure control, air or water flow rate control, and air handling unit temperature control, or 10 seconds or less for other control loops.

B. Control software algorithm and inputs and outputs for a single system or piece of equipment shall reside on a single controller and shall not be distributed amongst multiple controllers. If multiple pieces of equipment are to be interlocked, a single "Master" controller shall provide control for all interlocked pieces of equipment, i.e. an AHU and interlocked return fan and exhaust fans.

C. Control loop software algorithm for each analog control loop shall reside on same controller as inputs and outputs required for that specific control loop.

D. Networks that operate via polled response or other types of protocols that rely on central processors, file servers, or other such devices to maintain or manage peer-to-peer communications, shall have redundant components to maintain network in event of failure at central device. Provide automatic changeover (without operator intervention) to redundant device upon failure of any central type processor.

E. Floor Level Network (FLN) network shall be multi-drop digital transmission network utilizing BACnet MS/TP (76.8kbs) communication.

F. Each multi-drop trunk shall be within manufacturer's allowable line lengths without signal degradation. Multi-drop trunks shall be interfaced to system via standard EIA or other industry recognized interfaces so that single failure does not disrupt or halt network.

G. Communications between Building Level DDC Controllers and operator's workstations shall be peer-to-peer, allowing multiple users to access and use system simultaneously with no loss of system performance.

H. Provide levels of connected networks to connect all DDC Controllers, including terminal DDC Controller. Communications to terminal devices shall be similar to capabilities and functions of other DDC Controllers and shall be transparent to operator.

I. Quantity of nodes (devices connected) on any one FLN (MS/TP) shall not exceed 75% of maximum node capacity published by equipment manufacture and Building Controller processor usage shall not be greater than 30% nominal. Provide additional hardware to meet this requirement.

J. Alarm reports from DDC Controllers shall not be impeded by use of either remote or local monitor, or control stations on network either in access mode or programming mode.

K. Provide transient voltage surge suppression devices for controllers and other electronic devices requiring separate line voltage power source.

3.3 DIRECT DIGITAL CONTROLLERS

A. DDC Controller Usage:
   1. Select DDC Controller to provide speed of response required for each control loop type. Pressure, flow rate, and air handling unit temperature control must be via Building Level DDC Controller. Application specific DDC Controller may be used for other control loop types.
   2. Each DDC Controller shall have sufficient I/O capacity to perform specified control sequences and/or include points listed in any point schedules. If DDC Controller does not have sufficient capacity, provide additional slave panels to achieve required point count.
   3. Analog and critical safety discrete control loops shall have inputs and outputs into/from same DDC Controller. Analog control loops for major equipment (chilled water, hot water, convertors, air handling units, etc.) shall have PID control. Air terminal control loops may utilize floating point control from tri-state or Triac outputs from the controller but require some type of feedback device to prove position.
   4. Provide at least one Building Level DDC Controller per mechanical equipment room and, if required, at each PC workstation location.

5. For valves and dampers within 100 ft of associated DDC Controller, mount current to pneumatic (I/P) converter within DDC Controller panel or in adjacent panel. Otherwise mount I/P converters at valve or damper. Provide pressure gauges on main air, and all control output signals.

B. Point Capacity: Percentage based define how grouping of systems
1. Provide point capacity required plus spare I/O point capacity in each B-AAC. Spare I/O point capacity is defined as terminal connections, which are ready to accept digital or analog inputs, dry contacts for digital outputs, and variable voltage or current terminals for analog outputs. Universal type points are acceptable for both discrete and analog type points. Spare points do not include any input or output conversion devices.
2. Provide 10% spare points in each B-AAC.

C. Building Controllers:
1. Provide one BBMD in each IP subnet.
2. BACnet UDP port number to always be set to 47808 (BAC0).

D. Gateways:
1. Gateways may be used for communication with non-BACnet (Owner Approved) control hardware subject to all the following limitations:
a. Non-BACnet control hardware shall not be used for controlling built-up units.
b. Non-BACnet control hardware shall not perform system scheduling functions.

E. Cabinets:
1. Provide local control cabinets for DDC Controllers. DDC Controller cabinets for air terminals may be used directly if enclosures are rated for NEMA 1. All cabinets shall utilize a single master key. Provide 2 spare key sets to Owner.
2. All control cabinets shall be labeled. Labels shall be keyed to the unique identifiers shown on the As-Built drawings.

F. Controller Firmware
1. Provide latest version of controller firmware. Include firmware updates for period of one year after system acceptance, coinciding with warranty period. If the upgrade of firmware causes the need to upgrade or reconfigure/reprogram related systems, controllers or software, Contractor shall notify Owner prior to upgrade and provide additional work scope in coordination with other Contractors, as required, at no cost to Owner.

3.4 OPERATOR/ENGINEERING WORKSTATIONS

A. None. Refer to EIOS.

3.5 DDC SOFTWARE INSTALLATION

A. Operating system (OS): Contractor shall install the OS on workstations and laptops and configure usernames and passwords.

B. Virus Protection software: Contractor shall install the virus protection software on each server, laptop and workstation and shall configure weekly virus scans.

C. Contractor shall install and configure all software packages required to maintain and configure all types of controllers provided as part of this project on each engineering workstation.

D. Software from panels shall be permanently stored on USB Flash Drive at operator's workstation or Web Application Server. Provide auto re-boot feature on power up from system failure. System failures shall not necessitate manual reprogramming to restore normal system function.

E. Provide the latest version of all standard software, including operating system and control software. Include any software updates for period of one year, coinciding with warranty period. Beta released software shall not be used.

3.6 INITIAL PROGRAMMING

A. Control Contractor shall provide initial programming of controllers to accomplish sequences specified.

B. Provide back-up documentation per software manual submittals for all programs, in both written and electronic media formats.

C. Outputs, whether sequenced or not, shall have separate programmable hardware outputs. For air handling units, minimum outside air, maximum (economizer) outside air, return air, relief air, smoke dampers, heating valves, cooling valves, humidifier valves, etc., shall each have separate output.

D. BACnet Naming and Addressing
1. Every BACnet device shall have an assigned and documented MAC Address unique to its network. For Ethernet networks, document the MAC Address assigned at its creation. For MS/TP, assign from range as indicated by vendor documentation.
2. Assign unique numbers to each new network installed on the BACnet internetwork. Provide ability for changing the network number, either by device switches, network computer, or field operator interface. The BACnet internetwork (all possible connected networks) can contain up to 65,534 possible unique networks.
3. Every BACnet Building Controller (B-BC) and BACnet Router UDP port number shall be set to 47808 (BAC0).
4. Assign unique Device "Object_Identifier" property numbers or device instances for each device on the BACnet internetwork. Provide for future modification of the device instance number, either by device switches, network computer, or field interface. BACnet allows up to 4,194,302 possible unique devices per internetwork.
5. The Object Name property field shall support 32 minimum printable characters. Assign Object Name properties with plain-English names descriptive of the application. Examples include "Zone 1 Temperature" and "Fan Start/Stop".

E. Minimum BACnet Object Requirements
1. For the following points and parameters, use standard BACnet objects, where all relevant object properties can be read using BACnet's Read Property Service, and all relevant object properties can be modified using BACnet's Write Property Service: all device physical inputs and outputs, all set points, all PID tuning parameters, all calculated pressures, flow rates, and consumption values, all alarms, all trends, all schedules, and all equipment and lighting circuit operating status.
2. The Object Description property shall support 32 minimum printable characters. For each object, complete the description property field using a brief, narrative, plain English

description specific to the object and project application. For example: "HW Pump 1 Proof." Document compliance, length restrictions, and whether the description is writeable in the device PICS.

3. Support and provide Description and/or Device Type text strings matching signal type and engineering units shown on the points list.
4. Support and provide Inactive Text and Active Text property descriptions matching conditions shown on the points list.
5. For devices with scheduling capability, provide at least one Calendar Object with ten-entry capacity. Enable the writeable Date List property and support all calendar entry data types.
6. Use Schedule Objects for all building system scheduling.
7. Use Loop Objects or equivalent BACnet objects in each applicable field device for PID control. Regardless of program method or object used, allow authorized operators to adjust the Update Interval, Setpoint and all constraints associated with Object, such as Proportional Constant, Integral Constant, and Derivative Constant for Loop Object, using BACnet read/write services.

F. Minimum BACnet Service Requirements

1. Use commandable BACnet objects to control machinery and systems, providing the priority levels listed below.

   Priority Level - Application

   1. Manual-Life Safety
   2. Automatic-Life Safety
   3. (User Defined)
   4. (User Defined)
   5. Critical Equipment Control
   6. Minimum On/Off
   7. (User Defined)
   8. Manual Operator
   9. (User Defined)
   10. (User Defined)
   11. Load Shedding
   12. (User Defined)
   13. (User Defined)
   14. (User Defined)
   15. (User Defined)
   16. (User Defined)

G. Data Sharing:

1. Data communication from Building Controllers to Engineering Workstation and BAS web server shall be programmed to use Change of Value (COV) data sending and not continuous data polling to limit network traffic.
2. Data communication parameters for analog values shall be operator configurable and setup as follows:
   a. Minimum Send Time: 2 seconds
   b. b. Maximum Send Time: 60 seconds
   c. c. Send on Delta (COV):
      1) Space Temperature: ±0.5°F
      2) Process Temperature: ±0.5°F
      3) Air Pressure, AHU: ±0.05 inch-W.C.
      4) Relative Humidity: ±0.5%

5) Air Flow: ±200 cfm
6) Water Flow: ±50 gpm
7) Water Pressure ±0.2 psi
8) Space Pressure: ±0.01 inch-W.C.

3. Digital data points shall be sent whenever a state change occurs.

H. Historical Trending:
1. All inputs and analog outputs shall be trended and shall be fully configured and operational. Sample time shall be 15 minutes.
2. Program historical file for run-times and quantity of start/stops of motor-driven equipment.
3. Trend logs are to be stored at the building controllers and uploaded to the BAS web server or data historian when the building controller trend buffer size reaches 90% full or every 30 minutes (FA).
4. Store data according to Universal Time Code. Timestamp all data.

I. Alarm/Event Management:
1. All alarm handling shall be fully configured with consistent alarm messages and priorities or category numbers to identify the system from which the alarm originates.

J. Provide programming of menus to assist new users in accessing screen displays of each point group. Point groups (user definable) shall be initially arranged by DDC Controller for major equipment and by floor and area for terminal devices. Terminal devices shall also be grouped by air handling system where applicable.

K. When adding to an existing system, groupings, tag names, descriptions, engineering units, etc. shall match the existing system. Transitions from the existing system to the new system shall be seamless in look, functionality, and operation. Controls Contractor shall verify with Owner if any standard naming conventions are being used and continue with those naming conventions when applicable.

L. Program historical file for run-times and quantity of start/stops of motor driven equipment.

M. Program maintenance alarms based on run-times and quantity of start/stops for motor driven equipment.
1. Provide the following additional alarms:
a. Controller loss of communications for each controller.
b. Controller battery alarm for each controller (where available).
c. Out-of-range, bad, or missing data (fault) for each device.
2. Program alarms using the following levels:
3. Level 1 - Maintenance Alarm, requiring attention within 1 to 2 days. (Examples: 2-3°F temperature variance from set point; 15-25% relative humidity variance; etc.)
4. Level 2 - Low Level Alarm, requiring attention within 8 h, preferably during the same shift. (Examples: More than 3°F variance from set point, 30 percent relative humidity or more variance from set points; excess start/stops per day; etc.)
5. Level 3 - Critical Alarm, requiring immediate attention. (Examples: Non-operation of primary equipment; H-O-A overrides; failure of controllers, routers and repeaters.)
6. Level 1 and 2 alarms shall not interrupt current user operation, but shall be logged into alarm summary file, indicating status, acknowledgment, and by whom. Level 3 alarms shall interrupt user via audible and/or flashing warning until acknowledged, without losing any work in progress. When alarms are acknowledged, program shall display point group or appropriate graphic display. Level 3 alarms shall also be logged into alarm summary file in similar manner as Level 1 and 2 alarms.

N. Alarm Suppression

System Characteristics			Associated Equipment Alarm Suppression				
System	**Alarm Inputs**	**All Temperature Alarms**	**AHU Temp. Alarm - High**	**AHU Temp. Alarm - Low**	**Zone Temp. Alarm - High**	**Zone Temp. Alarm - Low**	**Zone Airflow Alarm - Low**
Fire Alarm	General Alarm	X					
Schedules	Unoccupied	X	X	X	X	X	X
AHU	Status Off (Alarm or Normal)		X	X	X	X	X
AHU	Supply Temperature – High		X		X		
AHU	Differential Pressure – Low		X	X	X	X	X

O. Time Schedules:
1. Provide time schedules for HVAC components/systems as indicated in Control Sequences.
2. All time schedules shall be fully configured with weekly schedules and all holidays identified by the Owner.
3. Time schedules are to reside in the Building Controllers.

P. Data Analytic Sequences to be programmed above and beyond sequence of operations if applicable.
1. Data analytics: If any of the following faults are proven true at any time, the BAS shall issue a fault report to the BAS workstation stating the fault name and the value of all associated BAS points.
   a. Cooling coil control valve leaking fault - cooling coil control valve is commanded closed (0%) and cooling coil leaving air temperature is 4°F (FA) below mixed air temperature.
   b. Low flow fault - cooling coil control valve is commanded open (100%) and cooling coil leaving air temperature is 2°F (FA) above setpoint. (similar for pre-cooling coil control valve)
   c. Preheat coil control valve leaking fault - preheat coil control valve is commanded closed (0%) and preheat coil leaving air temperature is 4°F (FA) above global outside air temperature.
   d. Low flow fault - preheat coil control valve is commanded open (100%) and preheat coil leaving air temperature is 2°F (FA) below setpoint.
   e. Mixed air temperature sensor fault - mixed air temperature is not between pre-cooling coil leaving air temperature and return air temperature.
   f. Cooling coil leaving air temperature sensor fault - cooling coil leaving air temperature is 2°F (FA) above mixed air temperature.
   g. Supply air temperature sensor fault - supply air temperature sensor is 0°F (FA) below or 5°F (FA) above cooling coil leaving air temperature.

h. Supply air static pressure - after fan sensor fault - supply air static pressure - 2/3 in duct is 0.0 in WG (FA) above supply air static pressure - after fan.
i. Supply airflow fault - supply fan speed command is 100% and static pressure is 0.0 in WG (FA) below setpoint.

3.7 POINT LIST

A. Contractor to provide points required to implement control sequences specified, whether they are listed in schedules or not. In addition to control points, provide additional points listed in point schedules or defined in Control Sequences.

B. All points shall be programmed with a point name and detailed description. Control contractor shall submit point naming convention to owner for approval prior to system programming.

C. Work jointly with Owner to develop point naming convention prior to start of programming.

END OF SECTION