SECTION 230900 – BUILDING AUTOMATION SYSTEM (BAS) CONTROLS

PART 1 - GENERAL

1.1 APPLICABLE REQUIREMENTS

A. All work to be furnished and installed under this section shall comply with all the requirements of General Conditions, Supplemental Conditions, Division 01 - General Requirements, Section 230500 - Basic HVAC Materials and Methods, and other Sections in Division 23 specified herein.

1.2 SCOPE

A. All work to be furnished and installed under this Section shall comply with all the requirements of Division 01, and shall include but not necessarily be limited to the following:

1. Integrate with existing direct digital Building Automation System (BAS) for the TI in scope with all hardware, software, controller, devices, sensors, conduit, wiring, and labor as required to provide complete and operational systems.
2. Provide control components and sequences of operation to meet or exceed the minimum requirements of the local applicable energy code and building codes.
3. The building’s existing centralized control system protocol is LonWorks. All new control systems shall interface accordingly.
    a. The network architecture shall consist of two levels, an Ethernet based primary network for all operator workstations, servers, and primary DDC controllers along with secondary Floor Level Networks (FLN) for terminal equipment application specific controllers
    b. Controls systems that shall be wired and installed via MSTP over BACNET. BACnet over IP will not be an approved method of installation.

B. General Requirements

1. The work includes designing, providing and installing a complete and fully operable building automation system as described in this Section of the Specification and as shown on the contract construction drawings and shall be in accordance with rules, regulations and standards as required by the authorities having jurisdiction. Any alternations to the quantity or location of the control panels shall be coordinated with the Electrical Contractor and General Contractor prior to bidding. Any BAS changes after bidding must be coordinated with Electrical Contractor and General Contractor at no additional cost to Owner.
2. Submit shop drawings of the entire control system components fully coordinated with major equipment suppliers' requirements. Provide proposed programming logic sequences of control functions on each system.
3. Installation of control components other than valves, dampers and sensing wells as required for a complete and workable system.
4. This Contractor shall furnish, install and coordinate the interlock and control wiring as specified and/or required for a complete and workable control system.

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5. Control dampers are specified and furnished in Section 233113 of these specifications. Provide damper actuators, wiring and conduit as required to operate all dampers as shown.
6. Upon completion of the installation, data entry and programming, provide complete validation and adjustment of specified control system through period of testing and Owner's acceptance. The control contractor shall perform a point-to-point check out of all newly installed points to verify point existence, proper end to end connection and correct SI units with the Owners Representative.
7. The entire program and sequence of operation with the final points list shall be verified by the Control Contractor, the Owner's Representative, and signed by both parties. A copy of the final program, sequence of operation, and points list shall be submitted to the Engineer for approval and inclusion with the operation and maintenance manuals.
8. Owner training on operation of the control system.
9. One-year warranty on workmanship and materials.
10. Interlocking of electrical systems and motors as shown on Drawings, except where specifically shown on electrical drawings.
11. All parameters identified in the controls sequence shall be adjustable at the front-end by the end user.
12. Contractor shall establish, tune, and coordinate all delays, timers, PID loops, and alarm latching. All PID loops shall maintain stable operational performance.

1.3 RELATED WORK IN OTHER SECTIONS

A. Refer to Division 0 and Division 1 for related contractual requirements.

B. Provide certificates of calibration for all sensors required for control and monitoring including temperature and pressure.

C. Refer to Division 23 and the following sections for Mechanical or Electrical Provision.

1. Division 01 - Submittal Procedures
2. Division 01 - Commissioning
3. Section 230500: Basic HVAC Materials and Methods
4. Section 230593: Testing, Adjusting, and Balancing
5. Section 232113: Hydronic Piping, Valves and Specialties
6. Section 233113: Air Distribution
7. Sections 237000 through 238999 equipment
8. Division 26 – Electrical Materials and Methods
9. Division 27 – Communications Systems
10. Division 28 – Electronic Safety and Security

D. Refer to Division 26 sections for Electrical Provisions. Sources of 120-volt electrical power as indicated on the electrical drawings and specifications for control system components furnished by this section. The controls contractor shall be responsible for all additional electrical distribution from these connection points to the control panels and other controls devices.

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E. BAS contractor will furnish, but not install the following:

1. Air flow measuring stations: furnish to mechanical installer and coordinate per manufacturer’s requirements.
2. requirements.
3. Control valves: furnish to mechanical installer and coordinate per manufacturer’s requirements.

1.4 DEFINITIONS

A. ASHRAE: American Society of Heating, Refrigerating, and Air-conditioning Engineers

B. BACnet: BACnet is a preferred communications protocol for building automation and control networks. It is an ASHRAE, ANSI, and ISO standard protocol. BACnet MS/TP is utilized with EIA/RS 485 hardware and BACnet/IP with Ethernet.

C. BAS: A system that optimizes the start-up and performance of HVAC equipment and alarm systems. A BAS greatly increases the interaction between the mechanical subsystems of a building, improves occupant comfort, lowers energy use, and allows off-site building control.

D. Modbus: One of industry standard communication protocols supported by NTMC. Developed by Modicon, Inc., North Andover, MA.

E. ODVA™: (Open DeviceNet Vendors Association) An international organization that supports computing network technologies based upon the Common Industrial Protocol (CIP). These include DeviceNet, EtherNet/IP, CIP Safety and CIP Sync.

F. RTD: Resistance temperature detector is a sensor whose resistance changes with temperature.

G. SCADA System (Supervisory Control And Data Acquisition): A type of industrial control system; a computer system which monitors and controls industrial, infrastructure, or facility-based processes.

H. Transducer: A device that converts variations in a physical quantity, such as pressure or brightness, into an electrical signal, or vice versa.

I. Transmitter: A set of equipment used to generate and transmit electromagnetic waves carrying messages or signals.

1.5 REFERENCE STANDARDS

A. The latest edition of the following standards and codes in effect and amended as of supplier's proposal date, and any applicable subsections thereof, shall govern design and selection of equipment and material supplied:

1. ASHRAE Guideline 36-High Performance Sequences of Operation of HVAC Systems
2. ANSI/ASHRAE Standard 135, BACnet.
3. International Building Code (IBC), including local State and Local amendments.

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4. UL 916 Underwriters Laboratories Standard for Energy Management Equipment. Canada and the US.
5. National Electrical Code (NEC).
6. FCC Part 15, Subpart J, Class A.
7. EMC Directive 89/336/EEC (European CE Mark).
8. UL-864 UUKL listing for Smoke Controls for any equipment used in smoke control sequences.

B. City, county, state, and federal regulations and codes in effect as of contract date.

C. Except as otherwise indicated, the system supplier shall secure and pay for all permits, inspections, and certifications required for his work, and arrange for necessary approvals by the governing authorities.

1.6 GENERAL REQUIREMENTS

A. Furnish a distributed logic BACnet-based control system and provide seamless integration into existing LonWorks control system. All new building controllers, application controllers, and all input/output devices shall communicate using the protocols and network standards as defined by ANSI/ASHRAE Standard 135-2016, BACnet. Provide all necessary BACnet-compliant hardware and software to meet the system's functional specifications. Provide Protocol Implementation Conformance Statement (PICS) for Windows-based control software and every controller in system, including unitary controllers. Provide additional integration controllers as required to operate seamlessly with existing LonWorks BAS.

B. Prepare individual hardware layouts, interconnection drawings, and software configuration from project design data.

C. Implement the detailed design for all analog and binary objects, system databases, graphic displays, logs, and management reports based on control descriptions, logic drawings, configuration data, and bid documents.

D. Design, provide, and install all equipment cabinets, panels, data communication network cables needed, and all associated hardware.

E. Provide and install all interconnecting cables between supplied cabinets, application controllers, and input/output devices. All Ethernet and structured cabling must be installed and tested per ANSI/TIA-568-D (latest revision) and any other applicable standards.

F. Provide and install all interconnecting cables between all operator's terminals and peripheral devices (such as printers, etc.) supplied under this section.

G. Provide complete manufacturer's specifications for all items that are supplied. Include vendor name of every item supplied.

H. Provide supervisory specialists and technicians at the job site to assist in all phases of system installation, startup, and commissioning.

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I. Provide a comprehensive operator and technician training program as described herein.

J. Provide as-built documentation, operator's terminal software, a software key for a minimum of one additional computer (coordinate with Owner's Representative if additional keys are required), diagrams, and all other associated project operational documentation (such as technical manuals) on approved media, the sum total of which accurately represents the final system.

K. Provide new sensors, dampers, valves, and install only new electronic actuators. No used components shall be used as any part or piece of installed system.

1.7 SYSTEM DESCRIPTION

A. A distributed logic control system complete with all software and hardware functions shall be provided and installed. System shall be completely based on ANSI/ASHRAE Standard 135-2016, BACnet and achieved listing under the BACnet Testing Laboratories BACnet. This system is to control all mechanical equipment, including all unitary equipment such as VAV boxes, fan-coils, air handlers, boilers, chillers, and any other listed equipment using native BACnet-compliant components.

B. The Building Automation System (BAS) application program shall be written to communicate specifically utilizing BACnet protocols. Software functions delivered on this project shall include password protection, scheduling (including optimum start), alarming, logging of historical data, full graphics including animation, after-hours billing program, demand limiting, and a full suite of field engineering tools including graphical programming and applications.

C. Building controllers shall include complete energy management software, including scheduling building control strategies with optimum start and logging routines. All energy management software and firmware shall be resident in field hardware and shall not be dependent on the operator's terminal. Operator's terminal software is to be used for access to field-based energy management functions only. Provide zone-by-zone direct digital logic control of space temperature, scheduling, runtime accumulation, equipment alarm reporting, and override timers for after-hours usage.

D. All application controllers for every piece of controlled equipment shall be fully programmable. Application controllers shall be mounted next to controlled equipment and communicate with building controller through BACnet LAN.

E. Room sensors shall be provided with digital readout that allow the user to view room temperature, CO2 or relative humidity, adjust the room setpoint within preset limits and set desired override time. User shall also be able to start and stop unit from the digital sensor. Include all necessary wiring and firmware such that room sensor includes field service mode. Field service mode shall allow a technician to balance VAV zones and access any parameter in zone controller directly from the room sensor. Field service mode shall have the ability to be locked out.

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1.8 QUALITY ASSURANCE

A. The BAS shall be designed, installed, commissioned, and serviced by contractor authorized and trained personnel. System provider shall have an in-place support facility within two (2) hours response time of the site with technical staff, spare parts inventory, and necessary test and diagnostic equipment.

B. The manufacturer and installer shall have a minimum of 5 years of demonstrated technical expertise and experience in the manufacture, installation and maintenance of BAS systems similar in size and complexity to this project. A list of successful past projects of similar type, size and complexity shall be submitted. In addition, a reference list of names, addresses and telephone numbers of the design Engineer and the Owner's Representative for each installation shall be provided. The references may be contacted and questioned about the timely delivery, installation, operation and service received for each installation.

C. The contractor shall provide experienced project manager for this work, responsible for direct supervision of the design, installation, start-up and commissioning of the BAS system.

D. The Bidder shall be regularly engaged in the design, installation and maintenance of BAS systems and shall have demonstrated technical expertise and experience in the manufacture, installation and maintenance of BAS systems similar in size and complexity to this project. Bidders shall provide a list of at least 10 projects, similar in size and scope to this project completed within the past 3 years.

E. Materials and equipment shall be manufacturer's latest standard design that complies with the specification requirements.

F. All BAS peer-to-peer network controllers, central system controllers and local user displays shall be UL Listed under Standard UL 916, category PAZX.

G. All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference and be so labeled.

H. Control system shall be engineered, programmed and supported completely by representative's local office that must be within 100 miles of project site.

I. Control components shall be products of the same manufacturer only, unless indicated otherwise and approved by Owner's Representative. Example – all valves shall by one manufacturer and all temperature sensors shall be by one manufacturer.

1.9 SUBMITTALS

A. System Documentation and Drawings

1. Include the following in two separate submittal packages in electronic format: "BAS Hardware" and "BAS Software". The software package may be submitted later than the hardware package for purposes of coordinating and developing site-specific items for review and comment by Owner's representative and

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Engineer; however, all components of both packages must be coordinated to avoid changes in either package derived from the other.

a. Hardware:

1) Complete bill of materials, and damper schedule.
2) Cut sheets of all equipment and components to be used as part of the BAS system with exact models, options, and accessories graphically indicated for review.
3) Manufacturer's instructions and drawings for installation, maintenance, and operation of all furnished items.
4) Overall system operation and maintenance instructions—including preventive maintenance and troubleshooting instructions.
5) For all system elements—building controller(s), application controllers, routers, and repeaters—provide BACnet Protocol Implementation Conformance Statements (PICS) as per ANSI/ASHRAE Standard 135-2016.
6) System configuration diagrams in simplified block format.
7) Electrical drawings that show all system internal and external connection points, terminal block layouts, and terminal identification.
8) Warranty information from manufacturer with any extended warranties clearly indicated.

b. Software:

1) Sample graphics package depicting one example of each system on the project for review by Owner’s representative.

a) At the Owner’s discretion, Contractor shall schedule a meeting between Owner’s representative and Contractor to review graphics package, solicit Owner’s feedback, and adjust package accordingly.

2) Complete sequences of operation for each system and piece of equipment. Sequences of operation shall use the Contract Documents as a starting point but shall not copy-and-paste the content of the Contract Documents as the sole submittal content; all submitted sequences of operation shall fully cover all aspects of operation in plain language format.
3) Provide complete description and documentation of any proprietary (non-BACnet) services and/or objects used in the system.
4) Floor plans indicating location of BAS controllers, room-level sensors, duct static pressure sensors, pipe differential pressure sensors, and other hardware.
5) All input/output object listings and an alarm point summary listing. Alarm points shall indicate latching/non-latching and delay.

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6) Complete list of all available and selected read/write points from integrated equipment controllers for review by Owner's representative and Engineer.
7) A list of all functions available and a sample of function block programming that shall be part of delivered system.

B. Project Management

1. The vendor shall provide a detailed project design and installation schedule with time markings and details for hardware items and software development phases. Schedule shall show all the target dates for transmission of project information and documents, and shall indicate timing and dates for system installation, debugging, and commissioning.

1.10 WARRANTY

A. Provide minimum one-year warranty from date of Substantial Completion, including all parts, material, labor and travel.

B. Refer to Section 230500 for additional warranty and Substantial Completion requirements.

C. Warrant work as follows:

1. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
2. Warrant all actuators for a period of five (5) years.
3. Respond during normal business hours within 24 hours of Owner's warranty service request.
4. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
5. If Owner determines that equipment and systems operate satisfactorily at the end of final start-up, testing, and commissioning phase, Owner will certify in writing that control system operation has been tested and accepted in accordance with the terms of this specification. Date of acceptance shall begin warranty period.
6. Provide updates to operator workstation software, project-specific software, graphic software, database software, and firmware that resolve Contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.
7. Exception: Contractor shall not be required to warrant reused devices except those that have been rebuilt or repaired. Installation labor and materials shall be warranted. Demonstrate operable condition of reused devices at time of Engineer's acceptance.

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D. Occupancy sensors: 5-year manufacturer warranty.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable BAS Manufacturers include:

1. Schneider Electric
2. Siemens

2.2 WEB INTERFACE

A. General

1. BAS supplier shall provide Web-based access to the system as part of standard installation. User must be able to access all displays of real-time data that are part of the BAS using a standard Web browser. Web browser shall tie into the network through Owner-supplied Ethernet network connection. Web page host may be a separate device that resides on the BAS BACnet network, but is not the BAS server for the control system. BAS server may be a separate computer from the Web page host device. The Web page software shall not require a per-user licensing fee or annual fees. The Web page host must be able to support simultaneous users with the ability to expand the system to accommodate an unlimited number of users.

B. Browser Technology

1. No special vendor-supplied software shall be needed on computers running browser. All displays shall be viewable and the webpage host shall directly access real-time data from the BAS BACnet network. Data shall be displayed in real-time and update automatically without user interaction. User shall be able to change data on displays if logged in with the appropriate user name and password.

C. Communications

1. Web page host shall support Ethernet network connections. A network connection shall be used to gather real-time data from all the BACnet devices that form the BAS. This network shall communicate using BACnet, allowing the Web page host to gather data directly from units on the local LAN or from other projects connected over a WAN. This network shall also provide the connection to the BAS server for Web page generation.
2. An Ethernet connection shall provide the physical connection to the Internet or an IP-based WAN. It shall be the port that is used for the browser to receive Web pages and data from the Web page host. The Web page host shall act as a physical barrier between the BAS network and the WAN or Internet connection that allows the browser to receive Web pages and data. The two separate network connections provide for a physical barrier to prevent raw BACnet traffic being exposed on the IP network.

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3. The Web page host shall provide for complete isolation of the IP and BACnet networks by not routing networking packets between the two networks.

D. Display of Data

1. Web page graphics shown on browser shall be replicas of the BAS displays. User shall need no additional training to understand information presented on Web pages when compared to what is shown on BAS displays. Web page displays shall include animation just as BAS displays. Fans shall turn, pilot lights shall blink, coils shall change colors, and so on.
2. Real-time data shall be shown on all browser Web pages. This data must be directly gathered using the BACnet network and automatically updated on browser Web page displays without any user action. Data on the browser shall automatically refresh as changes are detected without re-drawing the complete display.
3. It shall be possible for user from browser Web page to change data if the user is logged on with the appropriate password. Clicking on a button or typing in a new value shall change digital data. Using pull-down menus or typing in a new value shall change analog data.
4. Data displays shall be navigated using pushbuttons on the displays that are simply clicked on with the mouse to select a new display. Alternatively, the standard back and forward buttons of the browser can be used for display navigation.

E. Time Schedule Adjustment

1. Web access shall allow user to view and edit all schedules in the system. This includes three types of schedules: standard, holiday and event. Display of schedules shall show interaction of all schedules on a single display so user sees an overview of how all work together. User shall be able to edit schedules from this display.
2. Display of all three schedule types must show all ON times for standard, holiday and event schedules in different colors on a given day. In addition, OFF times for each must also be shown in additional colors. User shall be able to select from standard calendar what days are to be scheduled and same display shall show all points and zones affected. User shall be able to set time for one day and select all days of the week that shall be affected as a recurrence of that same schedule for that given day.
3. Schedule list shall show all schedules currently defined. This list shall include all standard, holiday and event schedules. In addition, user shall be able to select a list that shows all scheduled points and zones.

F. Logging of Information

1. User shall use standard browser technology to view all trend logs in system. User shall be able to view logged data in tabular form or graphical format. User shall be able to adjust time interval of logged data viewed and shall be able to adjust Y axis of data viewed in graphical format. User shall also be able to

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download data through the Web interface to local computer. Data shall be in CSV format.

G. Alarm Handling

1. Web interface shall display alarms as they occur. User shall be able to acknowledge alarms using browser technology. In addition, user shall be able to view history of alarm occurrence over a user-selected time frame. In addition, those alarms may be filtered for viewing per user-selected options. A single selection shall display all alarms that have not been acknowledged.

H. Web Page Generation

1. Web pages shall be automatically generated from the BAS displays that reside on the BAS server. User shall access Web page host through the network and shall initiate a Web page generation utility that automatically takes the BAS displays and turns them into Web pages. The Web pages generated are automatically installed on the Web page host for access using any computer's standard browser. Any system that requires use of an HTML editor for generation of Web pages shall not be considered.

I. Password Security and Activity Log

1. Access through Web browser shall utilize the same hierarchical security scheme as BAS system. User shall be asked to log on once the browser makes connection to Web page host. Once the user logs in, any and all changes that are made shall be tracked by the BAS system. The user shall be able to change only those items he or she has authority to change. A user activity report shall show any and all activity of the users who have logged in to the system, regardless of whether those changes were made using a browser or through the BAS workstation.

J. BACnet Communication

1. Web server shall directly communicate to all devices on the BAS network using BACnet protocol. No intermediate devices shall be necessary for BACnet communication.

2.3 BUILDING NETWORK CONTROLLER

A. Building Network Controller

1. BACnet Conformance

a. Building Network Controller shall be approved by the BACnet Testing Laboratories as meeting the BACnet Building Controller requirements.

B. Building network controller modules shall provide normal 7-day scheduling, holiday scheduling and event scheduling.

1. Logging Capabilities

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a. Logs shall be supported in the building network controller. Any object in the system (real or calculated) may be logged. Sample time interval shall be adjustable at the operator's workstation.
b. Logs may be viewed both on-site or off-site using WAN or remote communication.
c. Building network controller shall periodically upload trended data to networked operator's workstation for long-term archiving if desired.
d. Archived data stored in database format shall be available for use in third-party spreadsheet or database programs.

2. Alarm Generation

a. Alarms may be generated within the system for any object change of value or state (either real or calculated). This includes things such as analog object value changes, binary object state changes, and various controller communication failures.
b. Each alarm may be dialed out as noted elsewhere.
c. Alarm log shall be provided for alarm viewing. Log may be viewed on-site at the operator's terminal or off-site using remote communications.
d. Controller must be store alarms as BACnet event enrollment objects, with system destination and actions individually configurable.

3. Demand Limiting

a. Demand limiting of energy shall be a built-in, user-configurable function. Each controller module shall support shedding of up to 200 loads using a minimum of two types of shed programs.
b. Load shedding programs in building controller modules shall operate as coordinated with local utility.

4. Tenant Activity Logging

a. Tenant activity logging shall be supported by building network controller module.

C. MS/TP Module

1. MS/TP module shall support every listed function in this specification and the following.
2. Building controller MS/TP module communications shall be though BACnet MS/TP ASNI/EIA/RS-485-A LAN to all advanced application and application-specific controllers. Configure data rates to the maximum reliable settings (minimum bit-error rates) possible. ANSI/EIA/RS-422 & 232 based systems are not allowed.

D. Power Supply Module

1. Input for power shall accept between 17–30VAC, 47–65Hz.
2. Power supply module shall include rechargeable battery for orderly shutdown of controller modules including storage of all data in flash memory and for continuous operation of real-time clocks for minimum of 20 days.

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2.4 TRIDIUM NETWORK INTEGRATION

A. The Building Automation System (BAS) specified herein is an “integrated” system that utilizes a Tridium Niagara front end with BAS contractor’s native BACnet controllers. The BAS contractor shall furnish and install all Tridium Niagara based front end, hardware systems, and equipment to access and interface with a BACnet control system that utilizes unitary controllers to control all mechanical equipment, including all unitary equipment such as VAV boxes, fan-coils, etc., and any other listed equipment.

B. The BAS contractor shall develop, test, and commission all Tridium Niagara and GUI (Graphic User Interface) software applications for the HVAC control system. Additionally, the BAS contractor shall configure and commission the Ethernet communication network for the HVAC system.

C. Only BAS contractors that are Factory Authorized to sell and install the Niagara hardware and software are authorized to bid. The Niagara Authorized Contractor will have a minimum of three factory trained programmers. The programmers will have completed the Niagara Certification Program and work as full time employees, not sub-contractors.

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

E. Furnish a distributed logic BACnet-based control system. All building controllers, application controllers, and all input/output devices shall communicate using the protocols and network standards as defined by ANSI/ASHRAE Standard 135-2016, BACnet. Provide all necessary BACnet-compliant hardware and software to meet the system’s functional specifications. Provide Protocol Implementation Conformance Statement (PICS) for Windows-based control software and every controller in system, including unitary controllers.

F. Java Application Control Engine JACE (8000)

1. The Tridium JACE Controllers shall provide the interface between the LAN or WAN and the field control devices, and provide global supervisory control

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functions over the control devices connected to the JACE. It shall be capable of executing application control programs to provide:

a. Calendar functions
b. Scheduling
c. Trending
d. Alarm monitoring and routing
e. Time synchronization by means of an Atomic Clock Internet site including automatic synchronization
f. Integration of LonWorks controller data and BACnet controller data
g. Network Management functions for all LonWorks and BACnet based devices

2. The JACE (8000) must provide the following hardware features as a minimum:

a. Two Ethernet Port -10/100 Mbps
b. Two Isolated RS-485 and, if needed, RS -232 ports
c. One LonWorks Interface Port - 78KB FTT-10A with Weidmuller connector.
d. Two BACnet MS/TP interface Ports
e. Power supply 120 VAC
f. Battery Backup
g. Real-time clock
h. Processor: TI AM3352, 1GHz, or greater
i. 1 GB Ram, or greater
j. 4 GB flash memory.
k. 2 GB user storage
l. USB flash drive
m. Wi-Fi (Client or WAP)
n. Operating temperature: -20°C to 60°C

3. The JACE shall provide multiple user access to the system and support for ODBC or SQL. A database resident on the Tridium JACE shall be an ODBC compliant database or must provide an ODBC data access mechanism to read and write data stored within it.
4. The JACE shall support standard Web browser access via the Intranet/Internet. It shall support a minimum of 64 simultaneous users.
5. Event Alarm Notifications and actions

a. The JACE shall provide alarm recognition, storage, routing, management, and analysis to supplement distributed capabilities of equipment or application-specific controllers.
b. The JACE shall be able to route any alarm condition to any defined user location, whether connected to a local network or remote via dial-up telephone connection, or wide-area network.
c. Provide for the creation of a minimum of eight of alarm classes for the purpose of routing types and or classes of alarms, i.e.: security, HVAC, Fire, etc.
d. Provide timed (schedule) routing of alarms by class, object, group, or node.

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e. Provide alarm generation from binary object "runtime" and log event counts for equipment maintenance. The user shall be able to reset runtime or event count values with appropriate password control.
f. Control equipment and network failures shall be treated as alarms and annunciated.
g. Graphic with flashing alarm object(s)
h. The following shall be recorded by the Tridium JACE for each alarm (at a minimum):

1) Time and date
2) Location (building, floor, zone, office number, etc.)
3) Equipment (air handler #, accessway, etc.)
4) Acknowledge time, date, and user who issued acknowledgement.
5) Number of occurrences since last acknowledgement.

i. Alarm actions may be initiated by user defined programmable objects created for that purpose.
j. Defined users shall be given proper access to acknowledge any alarm, or specific types or classes of alarms defined by the user.
k. A log of all alarms shall be maintained by the JACE and/or a server (if configured in the system) and shall be available for review by the user.
l. Provide a "query" feature to allow review of specific alarms by user defined parameters.
m. A separate log for system alerts (controller failures, network failures, etc.) shall be provided and available for review by the user.
n. An Error Log to record invalid property changes or commands shall be provided and available for review by the user.

6. Data Collection and Storage

a. The JACE shall have the ability to collect data for any property of any object and store this data for future use.
b. The data collection shall be performed by log objects, resident in the Tridium JACE that shall have, at a minimum, the following configurable properties:

1) Designating the log as interval or deviation.
2) For interval logs, the object shall be configured for time of day, day of week and the sample collection interval.
3) For deviation logs, the object shall be configured for the deviation of a variable to a fixed value. This value, when reached, will initiate logging of the object.
4) For all logs, provide the ability to set the maximum number of data stores for the log and to set whether the log will stop collecting when full, or rollover the data on a first-in, first-out basis.
5) Each log shall have the ability to have its data cleared on a time-based event or by a user-defined event or action.

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7. All log data shall be stored in a relational database in the Tridium JACE and the data shall be accessed from a server (if the system is so configured) or a standard Web Browser.
8. All log data, when accessed from a server, shall be capable of being manipulated using standard SOL statements.
9. All log data shall be available to the user in the following data formats:
    a. HTML
    b. XML
    c. Plain Text
    d. Comma or tab separated values
10. Systems that do not provide log data in HTML and XML formats at a minimum shall provide as an alternative Microsoft SOL Server, Oracle Si or Expressa, Hyperion Solutions™ SOL Server.
11. The Tridium JACE shall have the ability to archive it's log data either locally (to itself), or remotely to a server or other Tridium JACE on the network. Provide the ability to configure the following archiving properties, at a minimum:
    a. Archive on time of day
    b. Archive on user-defined number of data stores in the log (buffer size)
    c. Archive when log has reached its user-defined capacity of data stores
    d. Provide ability to clear logs once archived
12. Audit Log
    a. Provide and maintain an Audit Log that tracks all activities performed on the Tridium JACE. Provide the ability to specify a buffer size for the log and the ability to archive log based on time or when the log has reached the user-defined buffer size. Provide the ability to archive the log locally (to the Tridium JACE), to another Tridium JACE on the network, or to a server. For each log entry, provide the following data:
        1) Time and date
        2) User ID
        3) Change or activity: i.e., Change setpoint, add or delete objects, commands, etc.
13. Database Backup and Storage
    a. The Tridium JACE shall have the ability to automatically backup its database. The database shall be backed up based on a user defined time interval.
    b. Copies of the current database and, at the most recently saved database shall be stored in the Tridium JACE. An onboard micro SD card contains a real-time back up of the system software, database, graphics, license and ability to be relocated to a replacement controller in the event the original controller fails.

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c. The Tridium JACE database shall be stored, at a minimum, in XML format to allow for user viewing and editing, if desired. Other formats are acceptable as well, as long as XML format is supported.

14. A JACE with I/O boards shall not be used for the control of any equipment such as fan coil units, boilers, pumps, etc. A single Unitary or Programmable controller shall manage the control functions for a specific mechanical system.

G. MS/TP Module

1. MS/TP module shall support every listed function in this specification and the following.
2. Building controller MS/TP module communications shall be though BACnet MS/TP ANSI/EIA/RS-485-A LAN to all advanced application and application-specific controllers. Configure data rates to the maximum reliable settings (minimum bit-error rates) possible. ANSI/EIA/RS-422 & 232 based systems are not allowed.

H. Wireless Module

1. Integrated IEEE 802.11 a/b/g/n
2. The wireless function comes from the factory disabled and can be turned on or off from a selector switch and can also be turned off through software. It should be turned off when wireless is not being used. Both Client mode and Access Point mode are supported but cannot be run simultaneously. Broadcasting of the SSID can be turned off. For those using wireless please read the JACE 8000 WiFi document for proper configuration. It supports only WPA-PSK & WPA2-SPK security protocols. It has a single dual band antenna supporting 2.4 Ghz channels 1-11 & 5.8Ghz channels 36, 40, 44, 48, 149, 153, 157, 161, & 165.
3. Several wireless protocols can be used including: WiFi, Zigbee, Z Wave, Enocean, 3G, 4G LTE.

I. Power Supply:

1. Provide UPS for power supply-backup controller.

2.5 APPLICATION CONTROLLERS – GENERAL

A. All application controllers shall include universal inputs with 10-bit resolution that can accept 3K and 10K thermistors, 0–5VDC, 4–20mA, dry contact signals and a minimum of 3 pulse inputs. Any input on controller may be either analog or digital. Controller shall also include support and modifiable programming for interface to intelligent room sensor. Controller shall include binary outputs on board with analog outputs as needed.

B. All program sequences shall be stored on board controller in memory. No batteries shall be needed to retain logic program. All program sequences shall be executed by controller ten(10) times per second and shall be capable of multiple PID loops for control of multiple devices. Programming of application controller shall be completely modifiable in the field over installed BACnet LANs or remotely through modem

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interface. Operator shall program logic sequences by graphically moving function blocks on screen and tying blocks together on screen. Application controller shall be programmed using same programming tools as building controller and as described in operator workstation section. All programming tools shall be provided and installed as part of system.

C. Provide all application controllers with a minimum of 10% spare points for analog input, analog output, digital input and digital output signals.

2.6 APPLICATION CONTROLLER – UNITARY MECHANICAL EQUIPMENT

A. Provide one native BACnet application controller for each piece of unitary mechanical equipment that adequately covers all objects listed in object list for unit. All controllers shall interface to building controller through MS/TP LAN using BACnet protocol. No gateways shall be used. Controllers shall include input, output and self-contained logic program as needed for complete control of unit.

2.7 APPLICATION CONTROLLER – DUAL DUCT TERMINAL UNIT

A. Provide one BACnet application controller for each dual-duct terminal unit that adequately covers all objects listed in object list for unit. Systems that use two or more controllers for control of a dual-duct box shall be rejected. All controllers shall interface to building controller via MS/TP LAN using BACnet protocol. Controllers shall include two (2) on-board flow sensors, inputs, outputs and self-contained logic program as needed for control of units.

B. On-board flow sensor shall be microprocessor driven and pre-calibrated at the factory. Pre-calibration shall be at 16 flow points as a minimum. All factory calibration data shall be stored in memory. Calibration data shall be field adjustable to compensate for variations in box type and installation. All calibration parameters shall be adjustable through intelligent room sensor. Operator workstation, portable computers and special hand-held field tools shall not be needed for field calibration.

C. Provide duct temperature sensors at discharge of cold duct and hot duct for report of data at operator workstation.

2.8 AUXILIARY CONTROL DEVICES

A. Temperature Sensors (TS)

1. Duct air temperature (duct mounted, indoor location)

a. Thermistor type with 1/4" stainless steel probe and junction box. 10K ohm, type II, or as required for controller interface. Two-wire, loop powered 4-20 mA. Probe length as required to extend 25% (minimum) to 50% (maximum) into the width of duct. Manufacturer: Veris #TF Series, Dwyer Instruments #TE-DFG Series, Kele (Minco) #TT Series.

2. Outside air temperature (wall mounted location)

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a. Thermistor type with stainless steel or platinum probe and weather-proof aluminum junction box. 10K ohm, Type 2, or as required for controller interface. Two-wire, loop powered 4-20 mA. Probe encased in durable radiation shield with radiation solar shield. Manufacturer: Veris #TO Series, Dwyer Instruments #TE Series.

B. Intelligent Room Temperature Sensor (TS) with LCD Readout

1. Sensor shall contain a backlit LCD digital display and user function keys along with temperature sensor. Controller shall function as room control unit and allow occupant to raise and lower setpoint, and activate terminal unit for override use-all within limits as programmed by building operator. Sensor shall also allow service technician access to hidden functions as described in sequence of operation.
2. The intelligent room sensor shall simultaneously display room setpoint, room temperature, outside temperature, and fan status (if applicable) at each controller. This unit shall be programmable, allowing site developers the flexibility to configure the display to match their application. The site developer should be able to program the unit to display time-of-day, room humidity and outdoor humidity. Unit must have the capability to show temperatures in degrees Fahrenheit or Centigrade.
3. Override time may be set and viewed in half-hour increments. Override time countdown shall be automatic, but may be reset to zero by occupant from the sensor. Time remaining shall be displayed. Display shall show the word “OFF” in unoccupied mode unless a function button is pressed.
4. See sequence of operation for specific operation of LCD displays and function keys in field service mode and in normal occupant mode. Provide intelligent room sensors as specified in point list. Field service mode shall be customizable to fit different applications. If intelligent room sensor is connected to VAV controller, VAV box shall be balanced and all air flow parameters shall be viewed and set from the intelligent room sensor with no computer or other field service tool needed.

C. CO2 Sensors

1. Indoor space measurement (wall mounted):

a. Non-dispersive infrared sensor in high impact white ABS plastic enclosure. Input power 20 to 30 VDC/24 AC, 100 mA. Analog output 4-20 mA. Operating range 32°F to 122°F (0°C to 50°C). Measurement range of 0-2000 ppm with accuracy of +/- 30 ppm.
b. Manufacturers: Veris #CWE Series, Dwyer #CDT Series.

D. Occupancy Sensor

1. Low-profile, dual technology sensor with 360 degree detection. UL and cUL listed.
2. Construction:

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a. Dual-element, temperature-compensated pyroelectric sensor

3. Features:

a. Immunity to RFI and EMI to eliminate false triggers.
b. Time delay adjustment from 30 seconds to 30 minutes.
c. Two levels of sensitivity, adjustable with physical switch.
d. Isolated relay with normally open and normally closed outputs, rated 1A @ 24VDC/VAC.
e. 24VAC/VDC voltage +/- 10%.
f. Mounting hardware for ceiling tile or gypsum board with mud ring.

4. Manufacturers: Wattstopper (Legrand) #CI-24.

E. Leak Detector

1. Water leak detector connected to BAS to alarm on detecting the presence of water in the following locations:

a. Secondary condensate drip pan below air conditioning air handling units and fan coils located above spaces with electrical and/or electronic equipment.

2. Features:

a. Mounting: Base mounted.
b. Service: water of conductive fluids.
c. Sensing gap: Minimum 1/8” (3 mm) to maximum 1/4” (6 mm).
d. Switch type: DPDT relay.
e. External power: 1 A @ 24 VAC/DC.
f. Audible alarm: 85 dB @ 1’ distance (0.3 m).
g. Visual indicators:

1) Green to indicate power is supplied.
2) Red to indicate water is detected.

h. Temperature limits: 32 to 122°F (0 to 50°C).
i. Flammability: plenum rated electrical cable with length as required and UL-94 compliant housing.
j. Attached with 1/16” thick double sided adhesive urethane foam tape.

3. Manufacturers: Dwyer #WD3-LP-D2-A, Kele, Veris.

F. Differential Pressure Transmitters:

1. Duct Static Pressure Transmitter:

a. Differential pressure transducer with selectable range, +/- 1% accuracy, with push button auto-zero, LCD display.
b. Manufacturers: Veris #PX Series, Dwyer Instruments #MS2, Kele #DPA Series.

2. Building Static Pressure Transmitter:

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a. Differential pressure transducer with selectable range, +/- 1% accuracy, with push button auto-zero. Provide with AA05 ceiling mount static pressure pick up, LCD display.
b. Manufacturers: Veris #PX Series, Dwyer Instruments #MS2, Kele #DPA Series.

2.9 ACTUATORS

A. Electronic Actuators:

1. Size for torque required for damper seal at load conditions.
2. Coupling: V-bolt dual nut clamp with a V-shaped, toothed cradle.
3. Mounting: Actuators shall be capable of being mechanically and electrically paralleled to increase torque if required.
4. Overload protected electronically throughout rotation.
5. Fail-Safe Operation: Mechanical, spring-return mechanism
6. Electronic Fail-Safe Operation: Incorporate a visual indication of the fail safe status on the face of the actuator. The power fail position shall be field adjustable between 0 to 100% in 10% increments. The electronic fail safe shall have a 2-10 second adjustable operational delay.
7. Power Requirements (Spring Return): 24-V ac, maximum 10 VA at 24-V ac or 8 W at 24-V dc (running). Maximum 1 VA at 24-V ac or 1 W at 24-V dc (holding).
8. Proportional Actuators shall be fully programmable through an onboard EEPROM by using an external cable and software interface.
9. Temperature Rating: -22 to +122ºF.
10. Housing: Minimum requirement NEMA type 2 mounted in any orientation. Provide manufacturer’s NEMA 3R weatherproof enclosure if actuator is mounted outdoors.
11. Agency Listings: ISO 9001, cULus, CE or CSA
12. The manufacturer shall warrant all components for a period of 5 years from the date of production, with the first two years unconditional.
13. Manufacturers: Belimo, Siemens, Honeywell, Keystone #777.

2.10 ENCLOSURES

A. All controllers, power supplies and relays shall be mounted in enclosures.

B. Enclosures may be NEMA 1 when located in a clean, dry, indoor environment.

C. Indoor enclosures shall be NEMA 12 when installed in other than a clean environment.

D. Enclosures shall have hinged, locking doors.

E. Provide laminated plastic nameplates for all enclosures in any mechanical room or electrical room. Include location and unit served on nameplate. Laminated plastic shall be 0.125 inches thick and appropriately sized to make label easy to read.

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PART 3 - EXECUTION

3.1 EXAMINATION

A. Prior to starting work, carefully inspect installed work of other trades and verify that such work is complete to the point where work of this Section may properly commence.

B. Notify the Owner’s Representative in writing of conditions detrimental to the proper and timely completion of the work.

C. Do not begin work until all unsatisfactory conditions are resolved.

3.2 INSTALLATION (GENERAL)

A. Install in accordance with manufacturer's instructions.

B. Provide all miscellaneous devices, hardware, software, interconnections, installation, and programming required to ensure a complete operating system in accordance with the sequences of operation and point schedules.

3.3 LOCATION AND INSTALLATION OF COMPONENTS

A. Locate and install components for easy accessibility; in general, mount 48 inches above floor with minimum three (3) feet of clear access space in front of units. Obtain approval on locations from Owner’s Representative prior to installation.

B. Wall mounted temperature sensors will typically be mounted directly above or below light switches and comply with ADA height requirements. Coordinate with Owner, Architect and other trades to assure proper mounted locations prior to installation.

C. All instruments, switches, transmitters, etc., shall be suitably wired and mounted to protect them from vibration, moisture, and high or low temperatures.

D. Identify all equipment and panels. Provide permanently mounted tags for all panels.

E. Provide stainless steel or brass thermowells suitable for respective application and for installation under other sections, and sized to suit pipe diameter without restricting flow.

F. Occupancy sensors: provide hardware as necessary to install within ceiling type as shown in the Contract Documents. Install per manufacturer’s requirements for full coverage of occupant locations within space. Coordinate with other ceiling items.

3.4 CONDUIT

A. Conduit Requirements: all conduit shall with comply with minimum requirements of local authority having jurisdiction.

1. Low voltage wiring in concealed areas may be plenum rated. Low voltage wiring in exposed areas shall be enclosed in conduit.

a. All low voltage wiring exposed to weather shall be installed in conduit.

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b. Low voltage wiring in exposed areas, such as in mechanical, electrical, or service rooms, shall be installed in EMT conduit up to 10 feet above finished floor.

B. Provide rigid conduit for low voltage wring in walls for all wall mounted sensors, CO2 sensors, humidity sensors, etc. Conduit shall be run to 6” (minimum) above the ceiling and shall terminate with a bushing installed on the conduit end. Flexible conduit shall not be used.

C. Provide conduit for low voltage wiring above inaccessible ceilings.

D. Conceal all conduits, except within mechanical, electrical, or service rooms. Install conduit to maintain a minimum clearance of 12 inches (30 cm) from high-temperature equipment (i.e.-such as flues or high temperature pipes).

E. Conduit must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Conduit sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

F. Secure conduits with conduit clamps fastened to the structure and spaced according to code requirements. Conduits and pull boxes may not be hung on flexible duct strap or tie rods. Conduits may not be run on or attached to ductwork.

G. Size of conduit and size and type of wire type shall be the responsibility of the contractor in keeping with the manufacturer’s recommendations and NEC requirements, except as noted elsewhere.

3.5 LOW VOLTAGE INTERLOCKING AND CONTROL WIRING

A. All control and interlock wiring shall comply with national and local electrical codes, and Division 26 of this specification, Where the requirements of this section differ from Division 26, the requirements of this section shall take precedence.

B. All low-voltage wiring shall meet NFPA-70 (NEC) Article 725 Class 2 requirements. Low-voltage power circuits shall be subfused when required to meet Class 2 current limit.

C. Do not install Class 2 wiring (greater than 100 volts and protected by overcurrent device not over 20 amperes) in conduits containing Class 1 wiring (not exceeding 30 volts and 1000 volt-amperes). Boxes and panels containing line voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g. relays and transformers).

D. Unless otherwise noted, power wiring for all valve and damper actuators is Class 2. If the BAS contractor desires to substitute 120-volt actuators, the BAS contractor shall coordinate directly with the General Contractor and Electrical Contractor to provide all 120-volt wiring and conduit at no additional cost to the Owner.

E. Contractor shall provide step-down transformers as necessary.

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F. Install insulated bushings on all conduit ends and openings to enclosures. Seal top end of vertical conduits.

G. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block. Wire nuts are not acceptable.

H. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.

I. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.

J. Use color-coded conductors throughout with conductors of different colors.

K. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.

L. The contractor shall terminate all communications, control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.

3.6 COMMUNICATION WIRING

A. The contractor shall adhere to the wiring requirement previously listed.

B. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling

C. Do not install communication wiring in conduits and enclosures containing Class 1 or other Class 2 wiring.

D. Maximum pulling, tension, and bend radius for the cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.

E. Contractor shall verify the integrity of the entire network following cable installation. Use appropriate test measures for each particular cable.

F. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lighting arrestor shall be installed according to manufacturer’s instructions.

G. All runs of communication wiring shall be unspliced length when that length is commercially available.

H. All communication wiring shall be labeled to indicate origination and destination data.

I. Grounding of coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

J. BACnet MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:

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1. The network shall use shielded, twisted-pair or stranded cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot). Wire gauge and wire type shall be sized and coordinated with manufacturer load requirements and lengths of runs.
2. The maximum length of an MS/TP segment is 1200 meters (4000 ft) with AWG 18 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485.
3. The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
4. An MS/TP EIA-485 network shall have no T connections.

K. All Ethernet cabling, routers, hubs and switches for connecting 230900 furnished and installed control panels, servers and clients to the building Owner’s Ethernet network are the responsibility of the BAS contractor.

3.7 FIELD SERVICES

A. Prepare and start logic control system under provisions of this section.

B. Start up and commission systems. Allow sufficient time for startup and commissioning prior to placing control systems in permanent operation. Provide all labor and services as necessary to support testing and verification by third party commissioning authority.

C. Provide the capability for off-site monitoring at control contractor's local or main office. At a minimum, off-site facility shall be capable of system diagnostics and software download. Owner shall provide phone line for this service for one year or as specified.

D. Provide Owner's Representative with spare parts list. Identify equipment critical to maintaining the integrity of the operating system.

3.8 PROJECT RECORD DOCUMENTS

A. Project Record Documents: Upon completion of installation, submit electronic copies of as-built documents. The documents shall be submitted for approval prior to final completion and shall include:

1. Project Record Drawings. As-built versions of the submittal shop drawings.
2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of Part 3: “Control System Demonstration and Acceptance.”
3. Operation and Maintenance (O & M) Manual.
4. As-built versions of submittal product data.
5. Names, addresses, and 24-hour telephone numbers of installing contractors and service representatives for equipment and control systems.
6. Operator’s manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.

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7. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
8. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
9. Documentation of all programs created using custom programming language including setpoints, tuning parameters, and object database.
10. Graphic files, programs, and database on magnetic or optical media.
11. List of recommended parts with part numbers and suppliers.
12. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
13. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
14. Licenses, guarantees, and warranty documents for equipment and systems.
15. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
16. Exported final sequences, diagrams, and points lists from the BAS at time of turnover.
17. All selected read/write points from integrated equipment and their labels.

3.9 TRAINING

A. Engage a factory-authorized service representative with complete knowledge of Project-specific system installed to train Owner's maintenance personnel to adjust, operate, and maintain BAS system.

B. Provide tuition for at least one individual to attend for a one-week factory training class. If applicable, costs for travel, lodging and meals will be the responsibility of the Owner.

C. Extent of Training:

1. Base extent of training on scope and complexity of BAS system indicated and training requirements indicated. Provide extent of training required to satisfy requirements indicated even if more than minimum training requirements are indicated.
2. Inform Owner of anticipated training requirements if more than minimum training requirements are indicated.
3. Minimum Training Requirements:

    a. Provide not less than 16 hours of training total.
    b. Stagger training over multiple training classes to accommodate Owner's requirements. All training to occur before end of warranty period.

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c. Break down total days of training into not more than four separate training classes.

D. Training Schedule:

1. Schedule training with Owner 20 business days, four weeks minimum, before expected Substantial Completion.
2. Training to occur within normal business hours at mutually agreed on time. Unless otherwise agreed to, training to occur Monday through Friday, except on U.S. Federal holidays, with morning sessions and afternoon sessions as required. Training, including breaks and excluding lunch period, are not to exceed eight hours per day.
3. Provide staggered training schedule as requested by Owner's Representative.

E. Training Attendee List and Sign-in Sheet:

1. Request from Owner in advance of training a proposed attendee list with name, phone number, and email address.
2. Provide preprinted sign-in sheet for each training session with proposed attendees listed and no fewer than six blank spaces to add additional attendees.
3. Include preprinted sign-in sheet with training session number, date and time, instructor name, phone number, email address, and brief description of content to be covered during session. List attendees with columns for name, phone number, and email address and a column for attendee signature or initials.
4. Circulate sign-in sheet at beginning of each session and solicit attendees to sign or initial in applicable location.
5. At end of each training day, send Owner an email with attachment of scanned copy (PDF) of circulated sign-in sheet for each session. Indicate which attendees, if any, joined for only part of the training.

F. Training Attendee Headcount:

1. Plan in advance of training for a minimum of two to four attendees.
2. Make allowance for Owner to add up to two attendee(s) at time of training.
3. Headcount may vary depending on training content covered in session. Attendee access may be restricted to some training content for purposes of maintaining system security.

G. Attendee Training Manuals:

1. Provide each attendee with all training materials and visual presentations in electronic format.

H. Instructor Requirements:

1. One or multiple qualified instructors, as required, to provide training.
2. Instructors must have a minimum of five years of instructional training and BAS system experience on not less than five past projects with similar BAS system scope and complexity to BAS system installed.

I. Organization of Training Sessions:

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1. Organize training sessions into logical groupings of technical content and to reflect different levels of operators having access to system. Plan training sessions to accommodate the following three levels of operators:
    a. Daily operators.
    b. Advanced operators.
    c. System managers and administrators.
2. Plan and organize training sessions to group training content to protect BAS system security. Some attendees may be restricted to some training sessions to ensure BAS system security.

J. Training Outline:

1. Submit training outline for review by Owner's Representative at least ten (10) business days before scheduling training.
2. Include in outline a detailed agenda for each training day that is broken down into each training session, training objectives for each training session, and synopses for each lesson planned.

K. On-Site Training:

1. Owner will provide conditioned classroom or workspace with ample desks or tables, chairs, power, and data connectivity for instructor and each attendee.
2. Provide training materials, projector, and other audiovisual equipment used in training.
3. Provide as much of training located on-site as deemed feasible and practical by Owner.
4. Include on-site training with regular walk-through tours, as required, to observe each unique product type installed with hands-on review of operation, calibration, and service requirements.
5. Use operator workstation that is to be used with BAS system in the training. If operator workstations are unavailable, provide temporary workstation to convey training content.

L. Off-Site Training:

1. Provide conditioned training rooms and workspace with ample tables desks or tables, chairs, power, and data connectivity for each attendee.
2. Provide capability to remotely access to Project BAS system for use in training where feasible.
3. Provide operator workstation for use by each attendee.

M. Training Content for Daily Operators as Appropriate for Installed BAS System:

1. Basic operation of system.
2. Understanding BAS system architecture and configuration.
3. Understanding each unique product type installed including performance and service requirements for each.

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4. Understanding operation of each system and equipment controlled by BAS system including sequences of operation, each unique control algorithm, and each unique optimization routine.
5. Operating operator workstations, printers, and other peripherals.
6. Logging on and off system.
7. Accessing graphics, reports, and alarms.
8. Adjusting and changing set points and time schedules.
9. Recognizing BAS system malfunctions.
10. Understanding content of operation and maintenance manuals including control drawings.
11. Understanding physical location and placement of BAS controllers and I/O hardware.
12. Accessing data from BAS controllers.
13. Operating portable operator workstations.
14. Review of BAS testing results to establish basic understanding of BAS system operating performance and HVAC system limitations as of Substantial Completion.
15. Running each specified report and log.
16. Displaying and demonstrating each data entry to show Project-specific customizing capability. Demonstrating parameter changes.
17. Stepping through graphics penetration tree, displaying all graphics, demonstrating dynamic updating, and direct access to graphics.
18. Executing digital and analog commands in graphic mode.
19. Demonstrating control loop precision and stability via trend logs of I/O for not less than 10 percent of I/O installed.
20. Demonstrating BAS system performance through trend logs and command tracing.
21. Demonstrating scan, update, and alarm responsiveness.
22. Demonstrating spreadsheet and curve plot software, and its integration with database.
23. Demonstrating on-line user guide, and help function and mail facility.
24. Demonstrating multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
25. Demonstrating the following for HVAC systems and equipment controlled by BAS system:
    a. Operation of HVAC equipment in normal-off, normal-on, and failed conditions while observing individual equipment, dampers, and valves for correct position under each condition.
    b. For HVAC equipment with factory-installed software, show that integration into BAS system is able to communicate with BAS controllers or gateways, as applicable.
    c. Using graphed trends, show that sequence of operation is executed in correct manner, and HVAC systems operate properly through complete sequence of operation including seasonal change, occupied and

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unoccupied modes, warm-up and cool-down cycles, and other modes of operation indicated.

d. Hardware interlocks and safeties function properly and BAS system performs correct sequence of operation after electrical power interruption and resumption after power is restored.

e. Reporting of alarm conditions for each alarm, and confirm that alarms are received at assigned locations, including operator workstations.

f. Each control loop responds to set-point adjustment and stabilizes within time period indicated.

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

N. Training Content for Advanced Operators as Appropriate for Installed BAS System:

1. Making and changing workstation graphics.
2. Creating, deleting, and modifying alarms including annunciation and routing.
3. Creating, deleting, and modifying point trend logs including graphing and printing on an ad-hoc basis and operator-defined time intervals.
4. Creating, deleting, and modifying reports.
5. Creating, deleting, and modifying points.
6. Creating, deleting, and modifying programming including ability to edit control programs offline.
7. Creating, deleting, and modifying system graphics and other types of displays.
8. Adding BAS controllers and other network communication devices such as gateways and routers.
9. Adding operator workstations.
10. Performing BAS system checkout and diagnostic procedures.
11. Performing BAS controllers operation and maintenance procedures.
12. Performing operator workstation operation and maintenance procedures.
13. Configuring BAS system hardware including controllers, workstations, communication devices, and I/O points.
14. Maintaining, calibrating, troubleshooting, diagnosing, and repairing hardware.
15. Adjusting, calibrating, and replacing BAS system components.

O. Training Content for System Managers and Administrators as Appropriate for Installed BAS System:

1. BAS system software maintenance and backups.
2. Uploading, downloading, and offline archiving of all BAS system software and databases.
3. Interface with Project-specific, third-party operator software.
4. Understanding password and security procedures.
5. Adding new operators and making modifications to existing operators.
6. Operator password assignments and modification.
7. Operator authority assignment and modification.
8. Workstation data segregation and modification.

P. Video of Training Sessions:

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1. Provide digital video and audio recording of each training session. Create separate recording file for each session.
2. Stamp each recording file with training session number, session name, and date.
3. Provide Owner with two copies of digital files on cloud and flash drives for later reference and for use in future training.
4. Owner retains right to make additional copies for intended training purposes without having to pay royalties.

END OF SECTION 230900

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