1. SECTION 23 09 00 BMS Instrumentation and Control
	1. GENERAL
		1. Related Sections
			1. SECTION 23 09 13, BMS Instrumentation and Control Devices
			2. SECTION 23 09 13.13, BMS Actuators and Operators
			3. SECTION 23 09 13.23, BMS Sensors and Transmitters
			4. SECTION 23 09 13.33, BMS Control Valves
			5. SECTION 23 09 13.43, BMS Control Dampers
			6. SECTION 23 09 23, BMS Direct Digital Control System
			7. SECTION 23 09 33, Variable Frequency Drives
			8. SECTION 23 09 80, Energy Dashboard
			9. DIVISION 26 - Wiring Devices
		2. References
			1. American National Standards Institute (ANSI)
				1. ANSI/ISA 5.5-1985 Graphic Symbols for Process Displays.
				2. ANSI/IEEE 260.1 2004, Standard Letter Symbols for SI and Certain Other Units of Measurements (SI Units, Customary Inch-Pound Units, and Certain Other Units).
				3. ANSI/ASHRAE 135-2016, BACnet - A Data Communication Protocol for Building Automation and Control Networks including the latest addenda.
		3. Acronyms, Abbreviations, and Definitions
			1. Acronyms used in BMS.
				1. BMS – Building Management System
				2. EMCS – Energy Management and Control System
				3. GUI – Graphical User Interface
				4. HVAC - Heating, Ventilation, Air Conditioning
				5. I/O - Input/output
				6. ISA - Industry Standard Architecture
				7. O&M - Operation and Maintenance
		4. Permits and Fees
			1. Per General Conditions of Contract.
			2. Submit certificate(s) of acceptance as applicable from authorities having jurisdiction to the Owner.
		5. General Description
			1. Refer to control schematics for general system architecture.
			2. Work covered by sections referred to above consists of fully operational BMS, including, but not limited to, following:
				1. Control devices as listed in I/O Summaries.
				2. Peripheral devices.
				3. Complete operating and maintenance manuals and field training of operators, programmers, and maintenance personnel.
				4. Acceptance tests, technical support during commissioning, full documentation.
				5. Wiring interface co-ordination of equipment supplied by others.
				6. Miscellaneous work as specified in these sections and as indicated.
		6. Standards Compliance
			1. All equipment and material to be from manufacturer's regular production, UL and/or ULC or CSA certified, manufactured to standard quoted plus additional specified requirements.
			2. Where UL and/or ULC or CSA certified equipment is not available to submit such equipment to inspection authorities for special inspection and approval before delivery to the site.
			3. Submit proof of compliance to specified standards with shop drawings and product data. A label or listing of the specified organization is acceptable evidence.
			4. In place of such evidence, submit an approval certificate from the testing organization, approved by the Owner, certifying that item was tested to accepted methods and that item conforms to their standard/code.
			5. For materials whose compliance with organizational standards/codes/specifications is not regulated by an organization using its listing or label as proof of compliance, furnish certificate stating that material complies with applicable referenced standard or specification.
			6. For retrofit projects only, existing sensors may be reused if the new controller supports a minimum 32-point linear interpolation translation table for the sensors.
			7. Installation shall be in accordance with national, state and local building and electrical codes as may be in force in the installation area.
		7. Work Included
			1. Provide a new building automation and control system to control and monitor the building’s mechanical and electrical systems.
			2. Provide new control valves, control dampers (gravity, fire and smoke control dampers by others), flow switches, thermal wells for temperature control, and air flow stations as necessary.
			3. Provide Variable Frequency Drives for HVAC equipment as specified herein.
			4. Provide submittal data sheets, control drawings schematics (in Visio or AutoCAD), data entry, pneumatic (as required) and electrical installation, programming, start-up, test and validation acceptance documentation, as-built documentation, maintenance manuals, and system warranties.
			5. All labor, material, equipment, and services not specifically referred to in this specification or on associated drawings that are required to fulfill the functional intent of this specification shall be provided at no additional cost to the Owner.
			6. The work covered by this specification and related sections consists of providing shop drawings, equipment, labor, materials, engineering, technical supervision, and transportation as required to furnish and install a fully operational BMS to monitor and control the facilities listed herein, and as required to provide the operation specified in strict accordance with these documents, and subject to the terms and conditions of the contract. The work in general consists of but is not limited to, the following:
				1. The preparation of submittals and provision of all related services.
				2. Furnish and install all components to achieve system operation, any control devices, conduit, and wiring, in the facility as required to provide the operation specified.
				3. Furnish complete operating and maintenance manuals and field training of operators, programmers, and maintenance personnel.
				4. Perform acceptance tests and commissioning as indicated.
				5. Provide full documentation for all applications and equipment.
				6. Miscellaneous work as indicated in these specifications.
		8. Work by Others
			1. Setting in place of valves and dampers, access doors, flow meters, water pressure, and differential taps, flow switches, thermal wells, fire and smoke control dampers, air flow stations, and current transformers shall be by others.
			2. Duct smoke detectors shall be provided under Division 26. Connection of auxiliary terminals of duct smoke detectors shall be wired to the BMS for monitoring purposes only by this section.
			3. High and low temperature thermostats shall be provided by this section.
			4. Switches, and power wiring to motors, starters, thermal overload switches, and contactors, are specified in Division 26. This Section includes the furnishing and installation of controls and wiring for automatic controls, electric damper and valve operators, terminal control units, interlocks, starting circuits, and wiring to power consuming control devices.
		9. BMS Contractor Qualifications
			1. Within 14 days of award of the contract the BMS contractor is to:
				1. Provide proof of having a local office within 75 miles of the project for at least 5 years, staffed by trained personnel capable of providing instruction, routine maintenance, emergency service on systems,
				2. Provide record of successful installations of similar size, performed by Contractor submitting the tender, showing successful experience with similar computer-based systems.
				3. Provide proof of having access to local supplies of essential parts and provide a 7-year guarantee of the availability of compatible spare parts after manufacturer’s declaration of obsolescence.
				4. Provide proof of having in-house staff with expertise in pneumatic controls where applicable.
				5. Provide Profiles for each employee who will be involved in this project.
		10. System Design Responsibility
			1. Design and provide all conduit and wiring linking all elements of system, including future capability.
			2. Design and provide all material for interfaces to existing pneumatic controls where applicable.
			3. Location of controllers to be approved by the Consultant before installation.
			4. Provide utility power or emergency power where directed and/or indicated on drawings, to controllers.
	2. PRODUCTS
		1. Quality Assurance
			1. All new Building Management System products on this project shall be provided by a firm that is a registered ISO 9001 and OHSAS 18001 manufacturer at the time of the bid.
			2. The Building Management System shall be furnished, engineered, installed, tested and calibrated by factory certified technicians qualified for this work. The contractor shall be Factory Authorized in good standing with the Manufacturer. Factory-trained technicians shall provide instruction, routine maintenance, and emergency service within 24 hours upon receipt of the request.
				1. Upon request, the installer shall present records of successful completion of factory training courses including course outlines.
				2. Upon request, the installer shall provide a letter from the manufacturer that they are a Factory Authorized installer in good standing with the Manufacturer.
	3. EXECUTION
		1. Co-ordination
			1. All work shall be performed at times acceptable to the Engineer/Construction Manager. Provide work schedule at the start of the job for the approval of the Engineer / Construction Manager. Schedule shall show when all staff and sub-contractors shall be on-site.
			2. Organize all your sub-contractors and ensure that they maintain the schedule.
			3. Full cooperation shall be shown with other sub-contractors to facilitate installations and to avoid delays in carrying out the work.
			4. Notify Engineer/Construction Manager of any changes to the schedule. Send any schedule changes and weekly progress reports via e-mail to Engineer and Construction Manager.
			5. Where, in the judgment of the Engineer/Construction Manager, the work could disrupt the normal operations in or around the building, contractor shall schedule work to eliminate or minimize interference.
			6. When connecting to the existing systems, advise the Engineer/Construction Manager and obtain permission to so. Perform work at a time acceptable to the Engineer/Construction Manager and Owner.
		2. Supervision of Personnel
			1. Maintain qualified personnel and supporting staff at this project with proven experience in erecting, supervising, testing, and adjusting projects of comparable nature and complexity.
			2. Supervisory personnel and their qualifications are subject to the approval of the Owner.
			3. All personnel working on-site shall sign in as required by the Owner and shall wear company identification.
			4. When requested and for whatever reason, remove personnel and/or support staff from project. Take immediate action.
		3. System Design and Responsibility
			1. The drawings do not show conduit size or wire type to link the various elements of the system.
				1. The BMS contractor is responsible for designing these links given the present and future capabilities.
			2. The Contractor is responsible for supplying sufficient Controllers of all types to meet the intent of the specification.
			3. The quantity and point content of the Controllers must be approved by the Engineer prior to point installation.
		4. Products
			1. Materials and equipment shall be essentially the cataloged products of manufacturers regularly engaged in production of such materials or equipment and shall be manufacturer's latest standard design that complies with the specification requirements.
			2. Where two units of the same class of equipment are required, these units shall be products of a single manufacturer, and the component parts of the system shall be the products of a single manufacturer.
			3. Each major component of equipment shall have the manufacturer's name and address and the model and serial number on a nameplate securely attached in a conspicuous place.
		5. Electrical Work, Wiring and Safety
			1. Electrical work shall be in accordance with ANSI/NFPA 70 and the local Electrical Code.
			2. Based on project location, Regional Regulation Compliance Certifications (CSA C22.1) will be required.
			3. Electrical wiring, terminal blocks and other high voltage contacts shall be fully enclosed or properly guarded and marked to prevent accidental injury to personnel.
			4. All wiring shall conform to the most stringent requirements of the local electrical authority having jurisdiction. Refer to Division 26 00 00 specification for electrical requirements, codes, and regulations.
			5. All wiring associated with and required by the BMS shall be the responsibility of this contractor.
				1. The term "wiring" shall be construed to include furnishing of wire, conduit, and miscellaneous material and labor as required to install a total working system.
				2. If departures from the contract documents are deemed necessary by the contractor, details of such departures, including changes in related portions of the project and the reasons, therefore, shall be submitted with the drawings to the Engineer for approval.
		6. Manufacturer's Recommendations
			1. Installation to be to manufacturer's recommendations. Provide printed copies of recommendations with shop drawings or product data.
		7. Nameplates
			1. Nameplates shall be provided for all control items listed or shown in the submittal and approved control diagrams.
			2. Each inscription shall identify its function, such as "mixed air controller", "cold deck sensor" in official languages, etc. and when applicable, its position.
				1. Size of nameplates shall be 1" by 3" minimum.
				2. Lettering shall be minimum 0.25" high normal black lettering.
				3. Submit duplicate samples of identification tags and lists of wording proposed for approval.
		8. Preliminary Design Review
			1. The BMS contractor shall submit a preliminary design document for review. This document shall contain the following information:
				1. Provide a description of the proposed system along with a system architecture diagram with the intention of showing the contractor's solution to meet this specification.
				2. Provide product data sheets and a technical description of all direct digital controller hardware required to meet specifications listed herein.
				3. Provide an overview of the BMS contractor’s local/branch organization, local staff, recent related project experience with references, and local service capabilities.
				4. Provide information on the BMS contractor’s project team including project organization, project manager, project engineer, programmers, project team resumes, and location of staff.
				5. Project Schedule of work indicating:

Intended sequence of work items

Start date of each work item

Duration of each work item

Planned delivery dates for ordered material and equipment and expected lead times

Milestones indicating possible restraints on work by other trades or situations

* + 1. Submittals
			1. Within sixty (60) days of award of contract and before start of construction, submit three (3) hard copies and one (1) electronic copy of manufacturer’s information and shop drawings.
				1. Drawings to be in AutoCAD or VISIO or REVIT and Sequence of Operations and Points List (Input/output Summary) shall be in Word and Excel format (latest versions) structured using menu format for easy loading and retrieval on the OWS.
			2. Provide in a completely coordinated and indexed package to assure full compliance with the contract requirements.
				1. Piecemeal submittal of data is not acceptable and such submittals will be returned without review.
				2. Information shall be submitted for all material and equipment the contractor proposes to furnish under terms of this contract work.
				3. Arrange the submittals in the same sequence as these specifications and reference at the upper right-hand corner of the specification section for which each submittal is intended.
				4. Submittals for each manufactured item shall be manufacturer's descriptive literature (equipment specification), equipment drawings, diagrams, performance and characteristic curves, and catalog cuts, and shall include the manufacturer's name, trade name, catalog model or number, nameplate data, size layout dimension, capacity, specification reference, applicable specification references, and all other information necessary to establish contract compliance.
			3. Control System Shop Drawings
				1. Schematic diagram of each controlled system. Label control points with point names.
				2. Bill of Material for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
				3. Specification sheets for each item including manufacturer's descriptive literature, drawings, diagrams, performance and characteristic curves, manufacturer and model number, size, layout, dimensions, capacity, etc.
				4. Control schematics with narrative description and control descriptive logic fully showing and describing operation and/or manual procedures available to operating personnel to achieve proper operation of the building, including under complete failure of the BMS.
				5. Shop drawings for each input/output point showing all information associated with each particular point including sensing element type and location; details of associated field wiring schematics and schedules; point address; software and programming details associated with each point; and manufacturer's recommended installation instructions and procedures for each type of sensor and/or transmitter.
		2. As-built Documentation (Operating and Maintenance (O&M) Manuals)
			1. As-built documentation shall consist of soft copies for all information described below
			2. The final documentation package shall include:
				1. Soft copies in Adobe PDF, Visio, AutoCad and Revit of all control drawings.
				2. Manufacturer’s technical datasheets for all hardware and software.
				3. Factory operating and maintenance manuals with any customization required.
				4. Soft copies only of programming and front-end software and each controller’s database.
				5. Provide clear, concise, printed and soft copy descriptions of all control sequences in the working language.
				6. Soft copy text files shall be in Microsoft Word format.
				7. Copy of all graphics files.
			3. Each instruction and reference manual shall be bound in hardback, 3-ring, binders or an approved equivalent shall be provided to the Engineer.
				1. Binders to be no more than 2/3 full.
				2. Each binder to contain index of full volume.
				3. One complete set of manuals shall be furnished prior to the time that the system or equipment tests are performed, and the remaining manuals shall be furnished at acceptance.
				4. The identification of each manual's contents shall be inscribed on the cover and spine.
				5. The manuals shall include the names, addresses and telephone numbers of each subcontractor installing equipment systems and of the local representatives for each item of equipment and each system.
				6. The manuals shall have a table of contents and be assembled to conform to the table of contents with the tab sheets placed before instructions covering the subject.
				7. Additionally, each manual shall contain a comprehensive index of all manuals submitted in accordance with this paragraph.
				8. Manuals and specifications shall be furnished which provide full and complete coverage of the following subjects:

Operational Requirements: This document shall describe in concise terms, all the functional and operational requirements for the system and its functions that have been implemented. It shall be written using common terminology for building operation staff and shall not presume knowledge of digital computers, electronics or in-depth control theory.

System Operation: Complete step by step procedures for operation of the system, including required actions at each operator station; operation of computer peripherals; input and output formats; and emergency, alarm and failure recovery. Step-by-step instructions for system startup, back-up equipment operation, and execution of all system functions and operating modes shall be provided.

Maintenance: Documentation of all maintenance procedures for all system components including inspection, periodic preventive maintenance, fault diagnosis, and repair or replacement of defective module. This shall include calibration, maintenance, and repair or replacement of all system hardware.

Test Procedures and Reports: The test implementation shall be recorded with a description of the test exercise script of events and documented as test procedures. A provision for the measurement or observation of results, based on the published test specification, forms the test reports. The procedures record and the results of these exercises shall be conveniently bound and documented together.

Configuration Control: Documentation of the basic system design and configuration with provisions and procedures for planning, implementing and recording any hardware or software modifications required during the installation, test, and operating lifetime of the system. This shall include all information required to ensure necessary coordination of hardware and software changes, data link or message format/content changes, and sensor or control changes in the event system modification are required, and to fully document such new system configurations.

* + 1. Manufacturer Training
			1. Manufacturer provided training on the use and operation of all products provided within these specifications shall be available for purchase and attendance by the Owner or his designated agent.
				1. Such training shall be of the similar curriculum as the training courses provided by the manufacturer to the Contractor.
				2. A manufacturer certified instructor shall give all training classes.
				3. A list of training courses with detailed course outline and duration with the associated cost shall be provided as part of the BMS submittals.
				4. Training shall be provided to the Owner or Owner’s assigned representatives.
				5. A minimum of ten (10) assigned representatives may me trained.
				6. A maximum of ten (10) assigned representatives may attend a training class. If more than ten (10) representatives require training, multiple training classes shall be provided.
				7. Provide training in two sessions:

First training session shall be a minimum of 40 hours and shall occur after substantial completion status has been attained for the BMS.

Second training session shall occur 45 days after the first session and shall be a minimum of 40 hours.

* + 1. Warranty
			1. The Contractor shall warrant the BMS, Software, Controllers, Sensors and associated field devices, including the installation and programming for a period of 2 year(s).
			2. The Warranty period shall be deemed to start on the day of written notice of Substantial Completion and shall complete at the end of the stated period.
			3. During the Warranty period, the Contractor shall provide materials, labor and associated expenses to repair, replace, update, and upgrade identified defects at its own expense.
			4. In the event of a critical failure, the Contractor shall respond within four (4) hours of notification during normal business hours and within eight (8) hours during off hours, weekends and holidays.

End of Section

1. SECTION 23 09 13 BMS Instrumentation and Control Devices
	1. GENERAL
		1. Related Sections
			1. SECTION 23 09 00, BMS Instrumentation and Control
			2. SECTION 23 09 13.13, BMS Actuators and Operators
			3. SECTION 23 09 13.23, BMS Sensors and Transmitters
			4. SECTION 23 09 13.33, BMS Control Valves
			5. SECTION 23 09 13.43, BMS Control Dampers
			6. SECTION 23 09 23, BMS Direct Digital Control System
		2. References
			1. Refer to Section 23 09 00 - References
		3. Acronyms, Abbreviations, and Definitions
			1. Refer to Section 23 09 00 - Acronyms, Abbreviations, and Definitions
	2. PRODUCT
		1. Computer Hardware
			1. General Description:
				1. The computer shall consist of commercially available general-purpose equipment manufactured by a recognized manufacturer with factory authorized service centers within \_\_\_\_ miles of the job site.
				2. The server shall be provided for centralized system control, information management, alarm management, and database management functions.
				3. All real-time control functions shall be resident in the standalone Network Control Unit (NCU) and local Field Control Units (FCUs).
			2. Provide a Server as detailed herein complete with Software, as described in Section 23 09 13.
			3. Provide Operator workstations as detailed herein complete with software, as described in Section 23 09 13.
			4. The system shall support standard Web browser access via the Intranet/Internet. It shall support a minimum of 32 simultaneous users. The BMS shall be provided with a minimum of 32 user licenses.
			5. Provide three copies of all Programming Software required for programming FCUs as described herein.
			6. Any computer with access to the BMS LAN shall be capable of displaying the systems in a graphical and dynamic format utilizing a standard web browser. Screen refresh shall be automatic. Manual refresh is not acceptable.
		2. Server Hardware Requirements
			1. The Server shall be a PC with minimum Intel i5 Quad-core 3.4 GHz processor with 16 GB RAM and a minimum of 250 GB SATA or SAS RAID Array (RAID 1 with hot spare suggested). It shall include a minimum of 4 USB ports. A minimum 21”, HDMI, DVI-D video interfaces, minimum 1024 x 768 resolution, 4x3 Widescreen, LED color monitor with a minimum 60 Hz refresh rate shall also be included.
			2. The server operating system shall be VMware ESXi v5.0 or newer with VM support and with the most recent service packs and system updates.
			3. Acceptable Manufacturers are:
				1. Dell
				2. Lenovo
				3. HP (Hewlett Packard)
			4. Connection to the BMS LAN network shall be via an Ethernet network interface card, 100/1000 Mbps.
			5. The server will be located in the Control Room.
			6. The server shall support all Network Control Units (NCU), OWS(s), and 3rd party mechanical/electrical systems connected to the Facility Management Control / Building Management System Local Area Network.
		3. Workstation Hardware Requirements
			1. The workstation shall be a PC with minimum Intel Core i5 Quad-core 3.4 GHz processor with 8 GB RAM and a 1TB SATA hard drive with 6 GB/s transfer rate. It shall include a minimum 32X CD-ROM drive and 4-USB ports. A minimum 21”, HDMI, DVI-D video interfaces, minimum 1024 x 768 resolution, 4x3 Widescreen, LED color monitor with a minimum 60 Hz refresh rate shall also be included.
			2. The operating system shall be Windows 10 Professional 64-bit computer with the most recent service packs and system updates.
			3. Acceptable Manufacturers are:
				1. Dell
				2. Lenovo
				3. HP (Hewlett Packard)
			4. Connection to the BMS LAN network shall be via an Ethernet network interface card, 100/1000 Mbps.
			5. Provide 1 Workstation(s).
			6. The Workstation(s) will be located in Control Room.
			7. Workstation(s) should be loaded with FCU Programming Tools.
		4. Portable Operator Terminal (POT)
			1. The laptop (or notebook) computer shall be equipped with a minimum of Intel i5 processor, minimum processing speed of 2 GHz with a minimum of 2 GB RAM, 250-gigabyte hard drive and two USB ports. The operating system shall be Windows 10 Professional and it shall include a web browser, Microsoft Edge, Firefox, etc. for access to the NCU/central BMS server via the Web.
				1. Connection to the EMCS network shall be via an Ethernet network interface card, 100/1000 Mbps.
				2. Provide a wireless (802.11 a/b/g/n) network interface card.
				3. The user shall have the ability to monitor and modify all the inputs, setpoints, outputs and operating parameters of any unitary controller on the network by connecting to any zone monitoring module anywhere on the network or tapping into the network at any controller.
				4. POT interface shall also function as portable interface to the field controllers.
				5. POT interface shall communicate on a peer to peer basis concurrently with Building Automation Systems or field controllers and shall be capable of integrating and dynamically displaying all monitoring points, setpoints, outputs and schedules for every unit on the same network.
				6. Provide 1 portable operator terminals.
		5. Uninterruptable Power Supplies
			1. Provide the OWS, Server, and each NCU with individual UPS to provide clean, reliable, noise-filtered power at all times and to protect and maintain systems operation throughout short-term power interruptions of up to 15 minutes duration.
			2. Acceptable Manufacturer is APC.
		6. Network Control Unit (NCU) and Graphical User Interface (GUI)
			1. Network Control Unit (NCU): Provide NCUs (NCU) for all equipment to be controlled as indicated on the Drawings and the sequence of operation specified in Section 23 09 93 - Sequence of Operations for HVAC Controls.
				1. NCUs (NCU) shall provide the interface between the LAN or WAN and the field control devices and provide global supervisory control functions over the control devices connected to the NCU. It shall be capable of executing application control programs to provide:

Calendar functions via native scheduling interface, iCalendar protocol applications such as the most current version of Outlook, Google Calendar, Apple iCal, etc.

Scheduling via built-in native scheduling interface, iCalendar protocol applications such as the most current version of Outlook, Google Calendar, Apple iCal, etc.

Trending to open source database formats such as MySQL and SQLite.

Alarm monitoring and routing with alarm recording and historical archiving to open source database formats such as MySQL and SQLite.

Time synchronization via internet time servers utilizing NTP methodology.

Integration of BACnet controller data.

* + - * 1. NCU must provide the following minimum hardware features:

A minimum of one Ethernet Port - 10/100 Mbps

Two RS-485 ports

Battery Backup Capability

Capable of operation over a temperature range of 32 to 122 degrees F.

Capable of operation over a humidity range of 0 to 80 percent RH, non-condensing

* + - * 1. NCU shall support standard Web browser access via the Intranet/Internet.
				2. Event Alarm Notification and actions:

NCU shall provide alarm recognition, storage; routing, management, and analysis to supplement distributed capabilities of equipment or application specific controllers.

NCU shall be able to route any alarm condition to any defined user location whether connected to a local network or remote via a wide-area network.

Alarm generation shall be selectable for annunciation type and acknowledgment requirements including but limited to:

To alarm.

Return to normal.

To fault.

Provide for the creation of alarm classes to route types and or classes of alarms, i.e.: Security, HVAC, Fire, etc.

Provide timed (schedule) routing of alarms by class, object, group, or node.

Provide alarm generation from binary object "runtime" and /or event counts for equipment maintenance. Users shall be able to reset runtime or event count values with appropriate password control.

* + - * 1. Control equipment and network failures shall be treated as alarms and annunciated.
				2. Alarms shall be annunciated in any of the following manners as defined by the user:

Screen message text.

Email of the complete alarm message to multiple recipients. Provide the ability to route and email alarms based on:

Day of week.

Time of day.

Recipient.

Graphic with flashing alarm object(s).

Twitter notification.

RSS feeds.

* + - * 1. The following shall be recorded by the NCU for each alarm (at a minimum):

Time and date.

Location (building, floor, zone, office number, etc.).

Equipment (air handler #, VAV, etc.).

End device (Temp sensor, smoke detector, etc.).

Acknowledge time, date, and user who issued acknowledgment.

* + - * 1. Alarm actions may be initiated by user-defined programmable objects created for that purpose.
				2. Defined users shall be given proper access to acknowledge an alarm or specific types or classes of alarms defined by the user.
				3. A log of all alarms shall be maintained by the NCU and/or a server (if configured in the system) and shall be available for review by the user.
				4. Provide a "query" feature to allow review of specific alarms by user-defined parameters.
				5. A separate log for system alerts (controller failures, network failures, etc.) shall be provided and available for review by the user.
				6. An Error Log to record invalid property changes or commands shall be provided and available for review by the user.
			1. Data Collection and Storage: NCU shall have the ability to collect data for any property of any object and store this data for future use.
				1. Data collection shall be performed by log elements, resident in the NCU that has, at a minimum, the following configurable properties:

Designating the log as interval or deviation.

For interval logs, the object shall be configured for time of day, day of week and the sample collection interval.

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.

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.

Each log shall have the ability to have its data cleared on a time-based event or by a user-defined event or action.

* + - * 1. All log data shall be stored in a relational SQL database in the NCU and the data shall be accessed from a server (if the system is so configured) or a standard Web browser.
				2. All log data, when accessed from a server, shall be capable of being manipulated using standard SQL statements.
				3. All log data shall be available to the user on-demand, or on scheduled intervals in the following data formats:

HTML.

Plain Text.

Comma or tab-separated values.

PDF.

Excel.

* + - * 1. Systems unable to provide log data in PDF and Excel formats at a minimum shall not be acceptable.
				2. NCU shall have the ability to archive its log data either locally (to itself), or remotely to a server or other NCU on the network. Provide the ability to configure the following archiving properties, at a minimum.

Archive on time of day.

Archive on user-defined number of data stores in the log (buffer size).

Archive when the log has reached its user-defined capacity of data stores.

Provide ability to clear logs once archived.

* + - 1. Database Backup and Storage: NCU shall have the ability to automatically backup its database. Database shall be backed up based on a user-defined time interval.
				1. Copies of the current database and the most recently saved database shall be stored in the NCU. The age of the most recently saved database is dependent on the user-defined database save interval.
				2. NCU database shall be stored, at a minimum, in SQL format to allow for user viewing and editing, if desired.
			2. Web Browser Clients: System shall be capable of supporting an unlimited number of clients using a standard Web browser such as Microsoft Edge, Mozilla Firefox, Google Chrome, and Apple Safari. Systems requiring proprietary software to enable a standard Web browser to be resident on the client machine. Manufacture-specific browsers will not be acceptable. To ensure site security for web-enabled browsing, plug-ins requiring the use of Java applets, Active-X or Flash technologies are not acceptable.
				1. Web browser software shall run on any operating system and system configuration that is supported by the Web browser. Systems that require specific machine requirements in terms of processor speed, memory, etc., to allow the Web browser to function with the EMCS, shall not be acceptable.
				2. Web browser shall provide the view of the system, in terms of graphics, schedules, calendars, logs, etc.
				3. Web browser client shall support at a minimum, the following functions:

User log-on identification and password shall be required. Security using the latest authentication and encryption techniques to prevent unauthorized access shall be implemented.

Graphical screens developed for the GUI shall be the same screens used for the Web browser client. Any animated graphical objects supported by the GUI shall be supported by the Web browser interface.

HTML programming shall not be required to display system graphics or data on a Web page. HTML editing of the Web page shall be allowed if the user desires a specific look or format.

Storage of the graphical screens shall be in the NCU, without requiring any graphics to be stored on the client machine. Systems that require graphics storage on each client are not acceptable.

Real-time values displayed on a Web page shall update automatically without requiring a manual "refresh" of the Web page.

Users shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:

Modify common application objects, such as schedules, calendars, and setpoints graphically.

View logs and charts.

View and acknowledge alarms.

Setup and execute SQL queries on log and archive information.

Graphic screens on the Web Browser client shall support hypertext links to other locations on the Internet or Intranet sites, by specifying the Uniform Resource Locator (URL) for the desired link.

* + - 1. Server Functions and Hardware: Provide system with a central server that supports all NCUs connected to the customer's network whether local or remote.
				1. Local connections shall be via an Ethernet LAN. Remote connections can be via ISDN, ADSL, T1, etc.
				2. It shall be possible to provide access to all NCUs via a single connection to the server. In this configuration, each NCU can be accessed from a remote standard Web browser by connecting to the server.
				3. Server shall provide the following functions, at a minimum:

Global Data Access: Provide complete access to distributed data defined anywhere in the system.

Distributed Control: Provide the ability to execute global control strategies based on control and data objects in any NCU in the network, local or remote.

Include a master clock service for its subsystems and provide time synchronization for all Network Control Units (NCUs).

Accept time synchronization messages from trusted precision Atomic Clock Internet sites and update its master clock based on this data.

Provide scheduling for all NCUs and their underlying field control devices.

Implement the BACnet Command Prioritization scheme (16 levels) for safe and effective contention resolution of all commands to NCUs. Systems not employing this prioritization shall not be accepted.

Provide central alarm management for all NCUs supported by the server including:

Routing of alarms to display, Twitter, RSS feed, email and SMS text via email.

View and acknowledge alarms.

Query alarm logs based on user-defined parameters.

Provide central management of log data for all NCUs supported by the server. Log data shall include process logs, runtime, and event counter logs, and error logs. Log data management shall include:

Viewing and printing log data.

Exporting log data to other software applications.

Query log data based on user-defined parameters.

* + - 1. System Programming: Graphical User Interface software (GUI) shall provide the ability to perform system programming and graphic display engineering as part of a complete software package.
				1. Provide a library of control, application, and graphic objects to enable the creation of all applications and user interface screens. Applications are to be created by selecting the desired control objects from the library, pasting them on the screen, and linking them together using a built-in graphical connection tool. Completed applications may be stored in the library for future use. Graphical User Interface screens shall be created in the same fashion. Data for the user displays are obtained by graphically linking the user display objects to the application objects to provide "real-time" data updates. Any real-time data value or object property may be connected to display its current value on a user display. Systems requiring separate software tools or processes to create applications and user interface displays shall not be acceptable.
				2. Programming Methods:

Provide the capability to copy objects from the supplied libraries, or a user-defined library to the user's application. Objects shall be linked by a graphical linking scheme by dragging a link from one object to another. Object links will support one-to-one, many-to-one, or one-to-many relationships. Linked objects shall maintain their connections to other objects regardless of where they are positioned on the page and shall show link identification for links to objects on other pages for easy identification.

Configuration of each object will be done through the object's property panel using fill-in-the-blank fields, list boxes, and selection buttons. The use of manufacturer-specific procedural language for configuration will not be accepted.

The software shall provide the ability to view the logic in a monitor mode. When on-line, the monitor mode shall provide the ability to view the logic in real-time for easy diagnosis of the logic execution. When off-line (debug), the monitor mode shall allow the user to set values to inputs and monitor the logic for diagnosing execution before it is applied to the system.

System shall support object duplication within a customer's database. An application, once configured, can be copied and pasted for easy re-use and duplication. All links, other than to the hardware, shall be maintained during duplication.

* + - 1. Object Libraries: Provide a standard library of objects for development and setup of application logic, user interface displays, system services, and communication networks.
				1. Objects in this library shall be capable of being copied and pasted into the user's database and shall be organized according to their function. Also, the user shall have the capability to group objects created in their application and store the new instances of these objects in a user-defined library.
				2. In addition to the standard libraries specified here, the manufacturer shall maintain an on-line accessible (over the Internet) library, available to all registered users to provide new or updated objects and applications as they are developed.
				3. All control objects shall conform to the control objects specified in the BACnet specification.
				4. The object library shall include objects to support the integration of devices connected to the NCU. At a minimum, provide the following as part of the standard library included with the programming software:

For BACnet devices, provide the following objects at a minimum:

Analog In

Analog Out

Analog Value

Binary In

Binary Out

Binary Value

Multi-State In

Multi-State Out

Multi-State Value

Schedule Export

Calendar Export

Device

For each BACnet object, provide the ability to assign the object a BACnet device and object instance number.

For BACnet devices, provide the following support at a minimum:

Read Property

Read Property Multiple

Write Property

Write Property Multiple

Who-has

I-have

Who-is

I-am

Ethernet

BACnet IP Annex J

MSTP

BACnet Broadcast Management Device (BBMD) function

Foreign Device Registrar

Routing

BACnet NAT Based Routing

* + - 1. MODBUS System Integration: Network Control Units (NCU) shall support the integration of device data from Modbus RTU or TCP control system devices. The connection to the Modbus system shall be via an RS485 or Ethernet IP as required by the device.
				1. Provide the required objects in the library, included with the Graphical User Interface programming software, to support the integration of the Modbus system data into the EMCS. Objects provided shall include at a minimum:

Read/Write Modbus AI Registers

Read/Write Modbus AO Registers

Read/Write Modbus BI Registers

Read/Write Modbus BO Registers

* + - * 1. All scheduling, alarming, logging and global supervisory control functions, of the Modbus system devices, shall be performed by the NCU.
				2. EMCS supplier shall provide a Modbus system communications driver. Provide with documentation of the system's Modbus interface and factory support at no charge during system commissioning.
			1. Acceptable Technologies
				1. ABB Cylon® ASPECT Platform
			2. NCU / FCU Programming Software
				1. Provide programming software for the Field Control Units (FCUs) that allow for the development of the FCU control logic and point management and Graphical User Interface screens.

A library of control, application, and graphic objects shall be provided to enable the creation of all applications and user interface screens.

Access to these functions shall be provided through Graphical User Interface software (GUI).

Applications are to be created by selecting the desired control objects from the library, dragging or pasting them on the screen, and linking them together using a built-in graphical connection tool.

Completed applications may be stored in the library for future use.

Graphical User Interface screens shall be created in the same fashion.

Data for the user displays is obtained by graphically linking the user display objects to the application objects to provide “real-time” data updates.

Any real-time data value or object property may be connected to display its current value on a user display.

Systems requiring separate software tools or processes to create applications and user interface displays shall not be acceptable.

Programming Methods:

Provide the capability to copy objects from the supplied libraries, or a user-defined library to the user’s application.

Objects shall be linked by a graphical linking scheme by dragging a link from one object to another.

Object links will support one-to-one, many-to-one, or one-to-many relationships.

Linked objects shall maintain their connections to other objects regardless of where they are positioned on the page and shall show link identification for links to objects on other pages for easy identification.

Object Configuration

Each object will be done through the object’s property sheet using fill-in-the-blank fields, list boxes, and selection buttons.

The use of custom programming, scripting language, or a manufacturer-specific procedural language for configuration will not be accepted.

The software shall provide the ability to view the logic with values being input to and output from the graphical blocks in real-time. (debug mode)

The system shall support object duplication within a client’s database.

An application, once configured, can be copied and pasted for easy re-use and duplication.

All links, other than to the hardware, shall be maintained during duplication.

Provides function to compare and calculate from multiple values from networked controllers (NCU and FCU).

As a minimum, the function shall calculate and compared the values and return the average, sum, highest, lowest, 3 highest, 3 lowest values and multi-state value count.

Auto-linking of objects to graphics

Auto-Encapsulate functionality (the automatic ability to group multiple programming objects into a new singular programming object).

Allow for uploading/downloading to/from multiple controllers

* + - 1. Utility Software
				1. Supply and install software products to allow the owner to access and manipulate the control schematic diagrams, and to access product data sheets in an electronic format.
				2. Enter all soft copy submissions; including "Record" drawings as specified herein (As-built Shop Drawings, Product Data and Maintenance Manuals) in OWS.
		1. Field Control Units (FCUs)
			1. All Field Control Units (FCUs) shall utilize the BACnet protocol and must be listed with the BACnet Testing Laboratory (BTL).
				1. Provide BACnet Controllers that are BACnet Testing Laboratory listed with profile types and applications as specified herein:

BACnet Building Controller (B-BC)

Provide BACnet B-BC FCUs for controlling Air Handling Units and Plant equipment such as Boilers, Chillers, Cooling Towers and primary Pump Systems.

BACnet Advanced Application Controller (B-AAC)

Provide BACnet B-AAC FCUs for controlling (secondary) terminal equipment such as, but not limited to, Variable Air Volume boxes (VAV), Rooftop Units, Heat Pumps, and Unit Vents.

* + - * 1. All BACnet Controllers shall use the following communication specifications and achieve performance as specified herein:

All controllers shall be able to communicate peer-to-peer without the need for a Network Control Unit (NCU).

Any controller on the MS/TP Data Link/Physical layer shall conform to BACnet BTL listing B-AAC and be able to act as a Master to allow for the exchange and sharing of data variables and messages with any other controller connected on the same communication cabling. Slave controllers are not acceptable.

Performance

Each BACnet MS/TP controller shall have a minimum of 64Kb of SRAM and 1Mb of external flash memory.

Each controller shall have a 32-bit microprocessor and support a BACnet protocol stack per the ANSI/ASHRAE Standard 135 current standard and the BACnet Device Profile supported.

Each BACnet controller on the BACnet MS/TP communications trunk shall provide a loading characteristic of a minimum 1/8th Load.

Each FCU shall have sufficient memory, to support its operating system and databases, including:

Control processes

Energy management applications

Alarm management applications

Historical/trend data for points specified

Maintenance support applications

Custom processes

Manual override monitoring

BACnet field controllers shall be provided for Heating and Cooling Plants, Air Handling Units, Make-up Air Units, Roof-top Units, Unit Ventilators, Fan Coils, Heat Pumps, Variable Air Volume Terminals, Unit Heaters, Exhaust Fans and other equipment to be under the control of the BMS and as shown on the drawings.

The application control program shall be resident within the same enclosure as the input/output circuitry, which translates the sensor signals.

Programmability

All Field Control Units (FCUs) shall be fully programmable and the programming software shall have a library of pre-built, tested, and user re-definable control sequences for a wide range of typical HVAC applications.

All control sequences programmed into the FCU shall be stored in non-volatile memory, which is not dependent upon the presence of a battery, to be retained.

FCU controllers that are not fully programmable and/or cannot retain programming as outlined in .2 are not acceptable.

BACnet Controllers shall communicate with the Network Control Unit (NCU) via a BACnet/IP connection at a baud rate of not less than 100 Mbps or via the RS485 MS/TP connection at a baud rate of not less than 76.8 kbps.

BACnet FCU to have a communications port for connecting a matching room temperature and/or humidity sensor and does not utilize any of the I/O points of the Controller.

The FCU and all other devices on the BACnet bus shall be accessible from this communications port.

The Contractor supplying the BACnet Controllers shall provide documentation for each device, with the following information at a minimum:

BACnet Device; MAC address, name, type, and instance number

BACnet Objects; name, type and instance number

It is the responsibility of the Contractor to ensure that the proper BACnet objects are provided in each BACnet controller, as required by the Point List located in the POINTS LIST section of this specification.

* + - * 1. Each FCU shall support:

Monitoring of the following types of inputs, without the addition of equipment outside the DDC Controller cabinet:

All controls shall have a minimum of 1 I/O point that is 100% universally configurable point (AI, DI, DO, AO).

Analog inputs of 4-20 mA, 0-10 Vdc, thermistor and RTD in the range 0 to 350,000 ohm.

Digital inputs from dry contact closure, pulse accumulators, voltage sensing.

Each FCU shall be capable of providing the following control outputs without the addition of equipment outside the DDC controller cabinet:

Digital outputs (contact closure for motor starters up to size 4).

Analog outputs of 4-20 mA and 0-10 Vdc.

* + - * 1. The FCU analog or universal input shall use a minimum 16-bit A/D converter.
				2. The FCU analog or universal output shall use a minimum 12-bit D/A converter.
				3. Optional on-board HAND-AUTO-OFF for analog and digital outputs with software configurability, LED status indicators and monitoring.
				4. Each FCU servicing primary equipment shall have a minimum number of spare points of each point type available on the controller for future connection.

Every FCU controller servicing any of Boiler, Chiller, Cooling Tower or primary Pumps, shall have a minimum of 20% spare capacity for each point type for future point connection.

Every FCU controller servicing an Air Handling Unit shall have a minimum of 20% spare capacity for each point type for future point connection.

Provide all processors, power supplies and communication controllers complete so that the implementation of a point only requires the addition of the appropriate point input/output termination module and wiring.

Manufacturers who have universally programmable points that can be software selected to support all four point types (AI, AO, DI and DO) may provide 25% of the specified spare capacity on Plant systems and AHUs. Universal points that support only input types or output types must provide the full spare points specified herein.

* + - * 1. Provide sufficient internal memory for the specified control sequences and have at least 25% of the memory available for future use.
				2. The FCU shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all panel components.

The controller shall provide both local and remote annunciation of any detected component failures or repeated failure to establish communication.

* + - * 1. Should the FCU memory be lost for any reason, the user shall have the capability of reloading the controller software via the BMS LAN OWS or Server.

Controllers requiring a local port to reload the controller software are not acceptable.

* + - * 1. Provide an onboard network communication jack for connection to the BACnet Network (RJ-45 or equivalent quick connect)
				2. Expansion I/O modules:

Each Expansion I/O module shall be capable of monitoring of the following types of inputs, without the addition of ancillary equipment:

Digital inputs from dry contact closure, pulse accumulators, voltage sensing.

Analog inputs of 4-20 mA, 0-10 Vdc, thermistor and RTD in the range 0 to 350,000 ohm.

The analog or universal input shall use a 16-bit A/D converter.

Controllers with less than 12-bit A/D converters must provide all analog input sensors with 4-20ma transmitters.

Each Expansion I/O module shall be capable of providing the following control outputs without the addition of equipment outside the DDC controller cabinet:

Digital outputs.

Optional Form C relay outputs.

Analog outputs of 0-10 Vdc.

The analog or universal output shall use a 12-bit D/A converter.

Optional on-board HAND-AUTO-OFF for analog and digital outputs with software configurability, LED status indicators and monitoring.

* + - * 1. Field Control Units (FCUs) utilizing BACnet/IP

Provide BACnet/IP FCUs with BACnet B-BC profile for primary equipment having greater than 12 points of control.

BACnet/IP FCU shall be 32-bit microprocessor-based operating at a minimum of 600 MHz.

They shall be multi-tasking, real-time digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules.

Each BACnet/IP FCU shall have a minimum of 512MB memory, and a minimum of 4GB non-volatile flash to support its operating system, connectivity and databases, including:

Control processes

Energy management applications

Alarm management applications

Historical/trend data for points specified

Maintenance support applications

Custom processes

Support for up to a minimum of 96 I/O points which are added via Expansion I/O modules.

A graphical interface with a common library of HVAC system image and animation such as AHU, MAU, Boiler Plant, Chiller Plant, and Rooftop Unit.

The BACnet/IP FCU shall have a real-time clock.

The BACnet/IP FCU will support the following communications protocols:

BACnet/IP, BACnet MS/TP, Modbus RTU and Modbus TCP utilizing the following connectivity:

DHCP and auto-DNS support.

Two (2) RJ-45 ports capable of Ethernet switch functionality and support for speeds up to 10/100 Mbps.

If the above functionality is not available, then an appropriate router(s) and switches must be supplied to provide the functionality.

BACnet MS/TP (9600 to 115200 baud) supporting up to a minimum of 24 additional BACnet MS/TP controllers in addition to the Expansion I/O modules.

Two (2) USB 2.0 ports.

Modbus

Modbus RTU RS-485 two-wire MS/TP communication or Modbus TCP Ethernet communication.

Each BACnet/IP FCU servicing primary equipment shall have a minimum number of spare points of each type available on the controller for future connection.

Every completed configuration of BACnet/IP FCU and Expansion I/O modules servicing any of Boiler, Chiller, Cooling Tower or primary Pumps, shall have a minimum of 20% spare capacity for each point type for future point connection.

Every completed configuration of BACnet/IP FCU and Expansion I/O modules servicing any Air Handling Unit shall have a minimum of 20% spare capacity for each point type for future point connection.

Provide all processors, power supplies and communication controllers complete so that the implementation of a point only requires the addition of the appropriate point input/output termination module and wiring.

Manufacturers who have universally programmable points that can be software selected to support all four point types (AI, AO, DI and DO) may provide 25% of the specified spare capacity on Plant systems and AHUs. Universal points that support only input types or output types must provide the full spare points specified herein.

Provide sufficient internal memory for the specified control sequences and have at least 25% of the memory available for future use.

* + - * 1. Every completed configuration of FCU and Expansion I/O modules servicing any of Boiler, Chiller, Cooling Tower or primary Pumps, shall be provided with on-board, monitored HAND-AUTO-OFF switches and potentiometer overrides.
				2. Manufacturers whose products do not have integral HAND-AUTO-OFF switches and potentiometer overrides must provide a seperate custom override panel with HAND-AUTO-OFF switches and external potentiometers with signals that are connected to the BMS control system. Provide the custom panel at each primary Air Handling Unit and Plant system including but not limited to Boiler, Chiller, Cooling Tower, and primary Pump systems.
				3. Unitary BACnet IP controllers should be able to cover applications from Fan Coil Units, Chilled Chillings, Heat Pumps, Unit Ventilators, Roof Top Units and can execute IAQ applications such as demand control ventilation. All Unitary controllers shall have the ability to control a high-power relay output up to 240 Volts and 8 Amps.
				4. Controllers shall be configurable by a mobile phone app along with the ability to balance air flow from a mobile phone app.
				5. All field controllers shall ship with a QR code on the controller that has the ability to pull up the controller datasheets and user manuals.
				6. Acceptable Products:

ABB Cylon® CB Line Series

ABB Cylon® FLXeon Series

* + - 1. Field Control Units (FCUs) - Variable Air Volume (VAV)
				1. The VAV FCU controllers shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC (±15%), allowing for power source fluctuations and voltage drops.
				2. The BMS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range.
				3. The controllers shall also function normally under ambient conditions of 32 ˚F to 122 ˚F and 5% to 90% RH (non-condensing).
				4. The VAV Actuator Shall be a Belimo Smart Actuator with intelligent position feedback for real-time positioning indication
				5. Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly.
				6. The VAV FCU shall include a built-in ‘flow thru’ differential pressure transducer.

The controller shall convert this value to actual airflow.

A single point differential pressure sensing device is not acceptable.

Membrane-based pressure differential transducer is not acceptable.

VAV FCU differential pressure transducer requiring periodic zero value airflow calibration is not acceptable.

* + - * 1. The BMS contractor shall verify the type of differential pressure sensors used in the existing boxes and ensure compatibility with the VAV FCU controllers.
				2. The VAV FCU shall include provisions for airflow balancing using a local airflow balancing interface or mobile application.
				3. An Intelligent Room Display (IRD) be used for balancing airflow.

In place of an IRD, a mobile application capable of balancing airflow is acceptable.

* + - * 1. The portable airflow balancing interface shall connect to the WI-FI BMS Network or the field BMS Network
				2. This tool shall allow the air balancer to manually control the action of the actuator including the following function: open VAV damper, close VAV damper, open all VAV dampers, and close all VAV dampers.
				3. Systems not able to provide an air balance mobile app or a portable airflow balancing interface or an Intelligent Room Display (IRD) (see section 23 09 13 2.11 Intelligent Room Displays (IRD)) capable of balancing airflow as part of the VAV FCU controller shall provide an individual full-time technician during the airflow balancing process to assure full balance compliance.
				4. The VAV box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within ±1.6 ˚F of setpoint at the room sensor location.
				5. Each controller shall also incorporate an algorithm that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space requirements.

This algorithm shall function to signal the respective controller to perform the required discharge temperature reset to maintain space temperature setpoint.

* + - * 1. It shall be possible to view and reset the space temperature, temperature setpoint, maximum airflow setting, minimum airflow setting, and actual airflow, through the BMS LAN.
				2. Provide BTL-Listed B-AAC BACnet MS/TP VAV controllers for this project.
				3. Acceptable Products:

ABB Cylon® CB Line CBV Series

ABB Cylon® FLXeon FBVi Series

* + 1. Local System Interface (LSI)
			1. A wall or IP65 rated panel mounted capacitive 7” (17.8cm) or 10” (25.4cm) touch-screen display that provides direct read/write access to any point on the network.
			2. The LSI shall provide the following:
				1. Consist of an alphanumeric and a multi-function intelligent keyboard.
				2. Support user authentication.
				3. Support connectivity to any NCU connected on the same IP network.
				4. Have a configurable graphical logo displayed on its default screen. This logo shall be a standard monochrome bitmap of 89 x 128 pixels that the user can replace.

Configuration of the display shall be made available within the system programming tools.

* + - * 1. Access through simple to use directional and entry buttons.
			1. The LSI shall be provided with a power adapter port and one RJ45 Ethernet port.
			2. Provide LSI(s) as shown on the mechanical drawings.
			3. Provide 10" (25.4cm) LSI(s) at each mechanical room panel (surface mount on face of panel).
			4. Acceptable Products:
				1. ABB Cylon® eXplore Series
		1. Intelligent Room Display (IRD)
			1. Intelligent Room Displays (IRD) shall communicate on a local 4-Wire network connected to any Field Control Unit (FCU) and shall provide ambient space condition sensing without the use of standard hardware I/O at the FCU level.
			2. Each IRD shall provide a Liquid Crystal Display (LCD) with the following minimum features:
				1. Minimum 1.4" x 1.2" display area
				2. Backlit
			3. The IRD shall be capable of displaying on its LCD the measured space temperature from 50 ˚F to 104 ˚F and/or humidity from 0 % RH to 100 % RH with one decimal
			4. The IRD shall be capable of displaying the following elements:
				1. Space temperature
				2. Cooling space temperature setpoint
				3. Heating space temperature setpoint
				4. Current heating or cooling mode
				5. Current occupancy mode
				6. Alarm condition
				7. Current time
			5. Each IRD shall provide a local keypad for a local user interface to perform navigation and adjustment of points configured as adjustable.
			6. The IRD shall be configured for FCU intended application requirements.
			7. Provide an IRD where indicated on the drawings each IRD shall provide at a minimum the following onboard integral I/O without the consumption of any inputs and/or outputs at the host FCU:
				1. Temperature Sensor

Sensing Element: 10k Thermistor

Accuracy: ±0.9 ˚F

Resolution: ±0.18 ˚F

Range: 40 ˚F to 104 ˚F

* + - * 1. Relative Humidity Sensor

Accuracy: ±3 % RH

Resolution: 1 % RH

Range: 10 % RH to 90 % RH

* + - 1. The IRD shall provide the function to fully balance the airflow of a Variable Air Volume (VAV) Terminal Control Unit (FCU).
				1. The IRD shall allow the air balancer to control the action of the VAV FCU including the following function: open VAV damper, close VAV damper, go to flow setpoint.
				2. The IRD shall allow the air balancer to enter flow-related parameters including minimum airflow, maximum airflow, and K factor.
				3. The IRD shall be capable of operating as a handheld tool for air balancing functions in situations where the IRD is not required as an installed sensor.
			2. The IRD menus provide the function to configure the Terminal Control Unit (FCU) shall define items such as I/O configurations, setpoints, and delays.
			3. The configuration tool or through an Intelligent Room Display (IRD) menus shall allow communication to the FCU application and activities such as inputs calibration, outputs override.
			4. The IRD shall provide password-protected menus or any other mechanism to prevent a local user to access advanced configuration menus including airflow balancing menu and network addressing.
			5. Provide a digital display sensor with Temperature, Humidity, Setpoint Adjustment and Override in all Office and Meeting Rooms.
			6. Provide a digital display sensor with Temperature and Override in all Common Areas.
			7. Acceptable Products:
				1. ABB Cylon® CBT-STAT Series
	1. EXECUTION
		1. Manufacturer's Recommendations
			1. Installation to be to manufacturer's recommendations. Provide printed copies of recommendations with shop drawings or product data.
		2. General Workmanship
			1. Install equipment, piping, and wiring or raceway horizontally, vertically, and parallel to walls wherever possible.
			2. Provide sufficient slack and flexible connections to allow for piping and equipment vibration isolation.
			3. Install equipment in readily accessible locations as defined by National Electrical Code (NEC) Chapter 1 Article 100 Part A.
			4. Verify wiring integrity to ensure continuity and freedom from shorts and ground faults.
			5. Equipment, installation, and wiring shall comply with industry specifications and standards and local codes for performance, reliability, and compatibility.
		3. Field Quality Control
			1. Work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances.
			2. Continually monitor field installation for code compliance and workmanship quality.
			3. Contractor shall arrange for work inspection by authorities having jurisdiction over the work.
		4. Wiring
			1. Control and interlock wiring and installation shall comply with national and local electrical codes, Division 26 00 00, and manufacturer's recommendations. Where the requirements of this Section differ from other Divisions, this Section shall take precedence.
			2. NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway as specified by NEC
			3. Low-voltage wiring shall meet NEC Class 2 requirements. Sub fuse low-voltage power circuits as required to meet Class 2 current limit.
			4. NEC Class 2 (current-limited) wires not in raceway but concealed and accessible locations such as return air plenums shall be UL listed for the intended application.
			5. Install wiring in raceway where subject to mechanical damage and at levels below 10 ft in mechanical, electrical, or service rooms.
			6. Install Class 1 and Class 2 wiring in separate raceways. Boxes and panels containing high-voltage wiring and equipment shall not be used for low-voltage wiring except for the purpose of interfacing the two through relays and transformers.
			7. Do not install wiring in raceway containing tubing.
			8. Run exposed Class 2 wiring parallel to a surface or perpendicular to it and tie neatly at 10 ft intervals
			9. Use structural members to support or anchor plenum cables without raceway. Do not use ductwork, electrical raceways, piping, or ceiling suspension systems to support or anchor cables.
			10. Secure raceways with raceway clamps fastened to structure and spaced according to code requirements. Raceways and pull boxes shall not be hung on or attached to ductwork, electrical raceways, piping, or ceiling suspension systems.
			11. Size raceway and select wire size and type in accordance with manufacturer's recommendations and NEC requirements.
				1. Include one pull string in each raceway 1" or larger.
			12. Use color-coded conductors throughout.
			13. Locate control and status relays in designated enclosures only. Do not install control and status relays in packaged equipment control panel enclosures containing Class 1 starters.
			14. Conceal raceways except within mechanical, electrical, or service rooms. Maintain minimum clearance of 6" between raceway and high-temperature equipment such as steam pipes or flues.
			15. Adhere to requirements in Division 26 where raceway crosses building expansion joints.
			16. Install insulated bushings on raceway ends and enclosure openings. Seal top ends of vertical raceways.
			17. Terminate control and interlock wiring related to the work of this section. Maintain at the job site updated (as-built) wiring diagrams that identify terminations.
			18. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 3ft in length and shall be supported at each end. Do not use flexible metal raceway less than 1/2" electrical trade size. Use liquid-tight flexible metal raceways in areas exposed to moisture including chiller and boiler rooms.
			19. Install raceway rigidly, support adequately, ream at both ends, and leave clean and free of obstructions. Join raceway sections with couplings and according to code. Make terminations in boxes with fittings. Make terminations not in boxes with bushings.
		5. Communications Wiring
			1. Communication wiring shall be low-voltage Class 2 wiring and shall comply with Article 3.7 (Wiring).
			2. Install communication wiring in separate raceways and enclosures from other Class 2 wiring.
			3. During installation do not exceed maximum cable pulling, tension, or bend radius specified by the cable manufacturer.
			4. Verify entire network's integrity following cable installation using appropriate tests for each cable.
			5. Install lightning arrestor according to manufacturer's recommendations between cable and ground where a cable enters or exits a building.
			6. Each run of communication wiring shall be a continuous length without splices when that length is commercially available.
				1. Runs that are longer than commercially available lengths shall have as few splices as possible using commercially available lengths.
			7. Label communication wiring to indicate origination and destination.
			8. Ground coaxial cable according to NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."
		6. Fiber Optic Cable
			1. Optical Cable. Optical cables shall be duplex 900 mm tight-buffer construction designed for intra-building environments. Sheath shall be UL listed OFNP in accordance with NEC Article 770. Optical fiber shall meet the requirements of FDDI, ANSI X3T9.5 PMD for 62.5/125 µm.
			2. Connectors. Field terminate optical fibers with ST type connectors. Connectors shall have ceramic ferrules and metal bayonet latching bodies.
			3. During installation do not exceed maximum pulling tensions specified by cable manufacturer. Post-installation residual cable tension shall be within cable manufacturer's specifications.
			4. Install cabling and associated components according to manufacturers' instructions. Do not exceed minimum cable and unjacketed fiber bend radii specified by cable manufacturer.

End of Section

1. SECTION 23 09 13.13 BMS Actuators and Operators
	1. GENERAL
		1. Related Sections
			1. SECTION 23 09 00, BMS Instrumentation and Control
			2. SECTION 23 09 13, BMS Instrumentation and Control Devices
			3. SECTION 23 09 13.23, BMS Sensors and Transmitters
			4. SECTION 23 09 13.33, BMS Control Valves
			5. SECTION 23 09 13.43, BMS Control Dampers
			6. SECTION 23 09 23, BMS Direct Digital Control System
		2. References
			1. Refer to Section 23 09 00 - References
		3. Acronyms, Abbreviations, and Definitions
			1. Refer to Section 23 09 00 - Acronyms, Abbreviations, and Definitions
	2. PRODUCT
		1. Actuators
			1. For dampers, the actuators used shall be provided from a single manufacturer
			2. For valves, the actuators used shall be provided from a single manufacturer
			3. Actuators shall be provided from a manufacturer registered under ISO9001:2000.
			4. Electronic Damper 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 Protection: Electronic overload or digital rotation-sensing circuitry without the use of end switches to prevent any damage to the actuator during a stall condition.
				5. Fail-Safe Operation: Mechanical, spring-return mechanism. Internal chemical storage systems, capacitors, or other internal non-mechanical forms of fail-safe operation are not acceptable.
				6. Power Requirements (Two-Position Spring Return): 24 or 120 VAC as required.
				7. Power Requirements (Proportional): Maximum 10 VA at 24 VAC or 8 W at 24 VDC.
				8. Temperature Rating: -22 to +122°F
				9. Housing: Minimum requirement NEMA type 2 / IP54 mounted in any orientation.
				10. Agency Listing: ISO 9001, UL, UL(C) and CSA C22.2 No. 24-93.
			5. Electronic Valve Actuators.
				1. Size for torque required for valve close off at 150% of total system (head) pressure for 2-way valves; and 100% of pressure differential across the valve or 100% of total system (pump) head differential pressure for 3-way valves.
				2. Coupling: Directly couple end mounts to stem, shaft, or ISO-style direct-coupled mounting pad.
				3. Mounting: Actuators shall be capable of being mechanically and electrically paralleled to increase torque if required.
				4. Overload Protection: Electronic overload or digital rotation-sensing circuitry without the use of end switches to deactivate the actuator at the end of rotation.
				5. Fail-Safe Operation: Mechanical, spring-return mechanism. Internal chemical storage systems, capacitors, or other internal non-mechanical forms of fail-safe operation are not acceptable.
				6. Power Requirements: Maximum 10 VA at 24 VAC or 8 W at 24 VDC.
				7. Maximum 1 VA at 24 VAC or 1 W at 24 VDC.
				8. Temperature Rating: -22 to +122°F
				9. Housing: Minimum requirement NEMA type 2 / IP54 mounted in any orientation.
				10. Agency Listing: ISO 9001, UL, UL(C) and CSA C22.2 No. 24-93.
			6. Terminal Unit Actuators
				1. Close-off (Differential) Pressure Rating: 200 psi.
				2. Coupling: V-bolt dual nut clamp with a V-shaped, toothed cradle or an ISO-style direct-coupled mounting pad.
				3. Power Requirements: Maximum 1 VA at 24 VAC or 1 W at 24 VDC.
				4. Temperature Rating: -22 to +122°F
				5. Housing Rating: Minimum UL94-5V(B) flammability.
				6. Agency Listing: CE, UL 60730-1A/-2-14, CAN/CSA E60730-1, CSA C22.2 No. 24-93, CE according to 89/336/EEC.
	3. EXECUTION
		1. Actuators
			1. General: Mount actuators and adapters according to manufacturer's recommendations.
			2. Electric and Electronic Damper Actuators.
				1. Mount actuators directly on damper shaft or jackshaft unless shown as a linkage installation.
				2. Link actuators according to manufacturer's recommendations.
				3. For low-leakage dampers with seals, mount actuator with a minimum 5° travel available for damper seal tightening.
				4. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately the 5° open position, manually close the damper and then tighten linkage.
				5. Check operation of damper-actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
				6. Provide necessary mounting hardware and linkages for actuator installation.
			3. Valve Actuators.
				1. Connect actuators to valves with adapters approved by actuator manufacturer.

End of Section

1. SECTION 23 09 13.23 BMS Sensors and Transmitters
	1. GENERAL
		1. Related Sections
			1. SECTION 23 09 00, BMS Instrumentation and Control
			2. SECTION 23 09 13, BMS Instrumentation and Control Devices
			3. SECTION 23 09 13.13, BMS Sensors and Transmitters BMS Actuators and Operators
			4. SECTION 23 09 13.33, BMS Control Valves
			5. SECTION 23 09 13.43, BMS Control Dampers
			6. SECTION 23 09 23, BMS Direct Digital Control System
		2. References
			1. Refer to Section 23 09 00 - References
		3. Acronyms, Abbreviations, and Definitions
			1. Refer to Section 23 09 00 - Acronyms, Abbreviations, and Definitions
	2. PRODUCT
		1. Sensors and Devices
			1. Input/output sensors and devices shall be closely matched to the requirements of the BMS controller for accurate, responsive, noise-free signal input/output. Control input response shall be high sensitivity and matched to the loop gain requirements for precise and responsive control.
			2. Sensors and transmitters shall be manually calibrated on-site so that the wiring length does not detract from the sensor accuracy specified.
			3. Provide guards (plastic or wire) for sensors, thermostats, and transmitters that are installed in public areas such as gymnasiums, classrooms, corridors, and vestibules.
			4. Temperature sensors shall have the following characteristics:
				1. Sensors shall have +/- 1 ˚F accuracy between 32 ˚F and 212 ˚F.
				2. Space temperature sensors

Shall consist of an element within a ventilated cover.

Space sensors located in mechanical rooms and public shall contain a network jack but shall have no ability to adjust temperature setpoint (Set Point Adjustment).

Space sensors shall be provided in accordance with the drawings and specifications with the following options:

Sensor complete with Network Jack

Sensor complete with Network Jack, and Set Point Adjustment

Sensor complete with Network Jack, and Override switch

Sensor complete with Network Jack, Set Point Adjustment, and Override switch

Sensor complete with Network Jack, Set Point Adjustment, Override switch and Fan Speed Selection.

* + - 1. RTD Transmitter
				1. Where reference is made on the drawings for a RTD transmitter, it shall be interpreted as follows:
				2. Transmitters shall meet at a minimum the following requirements.

Provide an RTD transmitter in configurations below meeting the following requirements:

100 ohm or 1000-ohm PT RTD

24V ac/dc power supply.

4-20 mA, 0-10Vdc or 0-5Vdc outputs compatible with BMS.

Electronics accuracy of +/-0.1% of span.

Operating temperature range of 32 ˚F to 158 ˚F. OSA only - operating temperature range of -40 ˚F to 185 ˚F.

Optional LCD display

* + - 1. Temperature Sensor – Outside Air
				1. Provide outside air temperature sensors as indicated within the field termination schedules and/or controls diagrams.
				2. Temperature sensors shall meet, at minimum, the following requirements:

Aluminum LB with PVC sun and windscreen.

Wall mount weatherproof enclosure with conduit entrance.

Thermistor or RTD compatible with BMS

* + - 1. Temperature Sensor – Duct Mounted – Single Point
				1. Provide duct mounted, single point, temperature sensor as indicated within the field termination schedules and/or controls diagrams as follows:

In ducts less than 10.8 ft² in cross-sectional area.

In ducts greater than 10.8 ft² in cross-sectional area if there is no heating coil and no cooling coil and no mixing of airflows of different temperatures upstream.

* + - * 1. Temperature sensors shall meet, at minimum, the following requirements:

0.25" stainless steel probe of length between one-third and two-thirds of the duct width.

Thermistor or RTD compatible with BMS, sealed in probe with 3-part moisture protection system.

Duct mounted ABS plenum-rated housing with conduit entrance. (Optional metal, weatherproof or no enclosure available)

* + - 1. Temperature Sensor-Wall Mounted
				1. Provide wall-mounted temperature sensors for non-public spaces as indicated within the field termination schedules and/or controls diagrams as follows.
				2. Temperature sensors shall meet, at minimum, the following requirements:

White protective enclosure.

The location to be selected by the Engineer/Architect at a height of 5 ft. No sensor shall be mounted until the Engineer/Architect gives specific location instructions.

Thermistor or RTD is compatible with BMS.

Optional set-point adjustment push-button override switch, LED indication, bi-metal, alcohol or LCD depended on owner requirement.

* + - 1. Temperature Sensor-Wall Mounted-Microprocessor Based
				1. Provide wall-mounted temperature sensors for non-public spaces as indicated within the field termination schedules and/or controls diagrams as follows.
				2. Temperature sensors shall meet, at minimum, the following requirements:

White protective enclosure.

The location to be selected by the Engineer/Architect at a height of 5 ft. No sensor shall be mounted until the Engineer/Architect gives specific location instructions.

Thermistor or RTD compatible with BMS.

3.5-digit LCD of room temperature and set-point

Push-button set-point adjustment-resistance or analog

Optional override switch

Optional LED

* + - 1. Temperature Sensor – Wall Mounted – Lobby, Hallways or Security Spaces
				1. Provide wall mounted stainless plate temperature sensors for lobbies and lobby vestibule spaces as indicated within the field termination schedules and/or control diagrams as follows.
				2. Temperature sensors shall meet, at minimum, the following requirements:

Stainless plate sensors to fit 100 x 50mm junction box, available with or without tamperproof screws.

Stainless plate sensors to fit 4”X2” junction box, available with or without tamperproof screws.

Thermistor or RTD compatible with BMS.

* + - 1. Temperature Sensor – Immersion - Thermowell Mounted
				1. Provide thermowell mounted temperature sensors as indicated within the field termination schedules and/or control diagrams as follows.
				2. Temperature sensors shall meet, at minimum, the following requirements:

Rigid 0.25" stainless steel probe of length, which is, at minimum, 20% of the pipe width.

Thermistor or RTD Compatible with BMS sealed in probe with three-part moisture protection system.

BMS shall report the monitored temperature with an accuracy of 1.0˚F.

ABS housing with conduit entrance. (Optional metal or weatherproof available)

Provide Brass or Stainless steel thermowell (316 or 304).

Provide with thermal grease to aid temperature sensing.

* + - 1. Temperature Sensor – Strap-On
				1. Provide strap-on mounted temperature sensors as indicated within the Field termination schedules and/or control diagrams or where thermowell mounted sensors cannot be mounted. Temperature sensors shall meet, at a minimum, the following requirements:

0.25" Stainless steel probe, 2"

Thermistor or RTD compatible with BMS, sealed in probe with a three-part moisture protection system

ABS housing with conduit entrance. (Optional metal or weatherproof available)

* + - 1. Temperature Sensor – Strap-On - Plate
				1. Provide strap-on mounted temperature sensors as indicated within the Field termination schedules and/or control diagrams or where thermo well-mounted sensors cannot be mounted. Temperature sensors shall meet, at minimum, the following requirements:

Thermistor or RTD compatible with BMS, sealed in probe with a three-part moisture protection system

A single point strap-on temperature sensor to be precision bonded to a 1.5" x 1.5" aluminum plate and adhered to 1.5" x 1.0" compressible foam. A 10" S/S Pipe clamp to be provided to secure the assembly to various sizes of pipe.

ABS housing with conduit entrance. (Optional metal or weatherproof available)

* + - 1. Relative Humidity Sensor – Wall Mounted
				1. Provide wall mounted relative humidity sensors as indicated within the Field termination schedules and/or control diagrams. Humidity sensors shall meet, at a minimum, the following requirements:

White protective enclosure

Sensor to be laser trimmed thermoset polymer-based capacitive type.

24 Vac/dc power supply

4-20 mA two-wire, 0-10 Vdc and 0-5 Vdc output proportional to relative humidity range of 0% to 100% and compatible with BMS.

2% accurate (5-95% RH). (3 & 5 % accurate units available)

Operating temperature range of 32˚F to 158˚F.

Reverse voltage protected and output limited.

Optional LCD display-SP and RH100A series

Optional setpoint adjustment-SP series

Optional push-button override-RH100A series

* + - 1. Relative Humidity Sensor – Duct Mounted
				1. Provide duct mounted relative humidity sensors as indicated within the Field termination schedules and/or control diagrams. Duct mounted relative humidity sensors shall meet, at minimum, the following requirements:

ABS housing with conduit entrance.

Sensor to be laser trimmed thermoset polymer-based capacitive type.

24 Vac/dc power supply.

4-20 mA two wires, 0-10 Vdc and/or 0-5 Vdc output proportional to relative humidity range of 0% to 100% and compatible with BMS.

2% accurate (5-95% RH). (3 & 5 % accurate units available)

9” probe length.

Operating temperature range of 32˚F to 158˚F.

Reverse voltage protected and output limited.

60-micron HDPE filter

* + - 1. Relative Humidity Sensor – Outside Air
				1. Provide OSA relative humidity sensors as indicated within the Field termination schedules and/or control diagrams. Humidity sensors shall meet, at minimum, the following requirements:

ABS hinged weatherproof housing with conduit entrance.

Sensor to be laser trimmed thermoset polymer-based capacitive type.

24 Vac/dc power supply

4-20 mA two-wire, 0-10 Vdc and 0-5 Vdc output proportional to relative humidity range of 0% to 100% and compatible with BMS.

2% accurate (5-95% RH).

Operating temperature range of 32˚F to 185˚F.

Reverse voltage protected and output limited.

* + - 1. Combination Relative Humidity and Temperature Sensors
				1. Where there is a requirement for the monitoring of both relative humidity and temperature at the same location, the BMS Contractor shall provide a combination of the relative humidity sensor and temperature sensor. The individual sensors must each meet the details of the specification above.
			2. Static Pressure Sensor – Duct Mounted
				1. Provide duct mounted static pressure sensors as indicated within the Field termination schedules and/or control diagrams. Static pressure sensors shall meet, at minimum, the following requirements:

Input range shall be appropriate for the application. Select range such that it covers from zero duct static pressure relative to the exterior of the duct up to a static pressure of between 20% and 50% in excess of the maximum static pressure that could be encountered in the duct relative to the duct exterior. Typically, for low-pressure commercial duct consider using a range of 0 to 0.0725 psi, for medium pressure duct use a range of 0 to 0.218 psi and for high-pressure duct use a range of 0 to 0.363 psi.

4-20mA, 0-5 or 0-10Vdc output is proportional to pressure input range compatible with BMS system.

1% Full-scale output accuracy

Operating temperature range of 32˚F to 140˚F.

Easily accessible, integral non-interacting zero adjustments.

Minimum overpressure input protection of two times rated input or 1.0 psi whichever is greater.

* + - 1. Room Pressure Sensor
				1. Provide space static pressure sensors as indicated within the Field termination schedules and/or control diagrams. Static pressure sensors shall meet, at minimum, the following requirements:

Input range of –0.00725 psi to +0.00725 psi.

4-20mA, 0-5 or 0-10Vdc output proportional to pressure input range compatible with BMS system.

1% accuracy of range

Operating temperature range of 0˚C to 60˚C.

Operating temperature range of 32˚F to 140˚F.

Easily accessible, integral non-interacting zero adjustments.

Minimum overpressure input protection of two times rated input or 1.0 psi whichever is greater.

* + - 1. Differential Pressure Sensor – Air (Filter/Coil Monitoring)
				1. Provide air differential pressure sensors as indicated in field termination schedules and/or control diagrams. Air differential pressure sensor shall meet, at minimum, the following requirements:

Sensors used for filter or coil differential pressures shall also have a display of the monitored differential pressure.

Output shall be 4-20mA, 0-10Vdc or 0-5Vdc output proportional to pressure input range compatible with BMS.

Select range as required, taking into consideration pressure drop across filter or coil. Typically, 0 to 0.0725 psi range for low-pressure commercial duct.

Operating temperature range of 32˚F to 140˚F.

* + - 1. Differential Pressure Switch – Air
				1. Provide air differential pressure switches as indicated in field termination schedules and/or control diagrams. Air differential pressure switches shall meet, at minimum, the following requirements:

An IP54 (NEMA 13) polycarbonate housing.

SPDT switch rated at 250 Vac at 1 amp.

Field adjustable range from 0.00725 psi to max range of device. Select range as required, taking into consideration pressure drop across filter or coil. Typically, 0 to 0.0725 psi range for low-pressure commercial duct.

Temperature range of –4˚F to 140˚F.

Setpoint adjustment knob with indication.

Automatic reset.

* + - 1. Airflow Sensor
				1. Provide airflow rate sensors and transducers as indicated in the Field termination schedules and/or control diagrams. Airflow rate sensors and transducer shall meet, at minimum, the following requirements:

Hotwire anemometer type.

Self-compensation for changes in air temperature.

Probe and transducer housing shall be constructed of durable PVC.

Probe shall be adjustable from 2"-7.25".

Power supply shall be 24 Vac/dc.

Output signal of 4-20 mA or 0-10Vdc proportional to airflow speed equal to 0-52.5 ft/s or 0-26.25 ft/s jumper selectable.

Air temperature range of 14˚F to 140˚F.

5% accuracy of measured value.

* + - 1. Water Pressure Sensor
				1. Provide water pressure sensors as indicated within the Field termination schedules and/or control diagrams. Pressure sensors shall meet the following requirements:

Operating range shall be suitable for the application. Select range such that it covers from zero pressure to twice the amount of pressure desired for control purposes or that could be encountered.

4-20 mA output proportional to water pressure.

0.25% accuracy of range.

Temperature range of -40˚F to 260˚F.

Overpressure input protection of a minimum two times rated input.

An optional ABS wiring housing is available for an interior application and weatherproof wiring housing is available for an exterior application.

17-4PH stainless steel wetted parts.

Burst pressure of a minimum five times rated input.

* + - 1. Water Differential/Gauge Pressure Sensor
				1. Provide water differential or gauge pressure sensors as indicated in the Field termination schedules and /or control diagrams. Water differential pressure sensors shall meet, at minimum, the following requirements:

Output of 4-20 mA, 0-10 or 0-5 Vdc proportional to the pressure sensed.

Momentary over pressure protection of five times the rated input.

Operating range shall be suitable for the application. Select range such that it covers from zero differential pressure up to a differential static pressure of 20% to 50% in excess of the maximum static pressure that could be encountered. Remember that if the sensor is used for the control of a chilled water bypass and is located across, for example, a chilled water AHU coil, the pressure drop of both the coil and the associated valve at full design flow have to be taken into account.

Accuracy of better than 1% of full-scale reading.

Valve tapping shall be furnished and installed by the Mechanical contractor. Coordinate with the Mechanical contractor.

* + - 1. Current Relay/Switch
				1. Provide current sensing relays as indicated in the Field termination schedules and/or control diagrams. Current sensing relays shall meet, at minimum, the following specifications:

Rated for the applicable load.

The output relay shall have an accessible trip adjustment over its complete operating range. Provide LED indication of relay status.

Current relay shall have input and output isolation via current transformer.

Current relay shall be self-powered with no insertion loss.

Relay shall be in a dustproof housing.

Accuracy to be <2% of full-scale max.

Temperature rating of 5˚F to 140˚F.

Whenever the status of a single-speed motor is monitored it shall be done via a current sensing relay.

The BMS contractor shall provide current sensing relays at the MCC starters.

The BMS contractor shall provide the current sensing relays for motors with local starters and no MCC starter.

* + - 1. Current Sensor
				1. Provide monitoring of the current as identified in Field termination sheets and/or control drawings. Current monitoring shall meet, at minimum, the following requirements:

4-20 mA, 0-10 or 0-5 Vdc output proportional to current draw.

Reverse polarity protected and output limited.

50/60 Hz operation.

Accuracy of better than 1%.

Operating temperature range of 32˚F to 158˚F.

* + - 1. Electronic to Pneumatic Transducers
				1. Provide electronic to pneumatic transducers as identified in the field termination sheets and/or controls drawings. Transducers shall include, at minimum, the following:

Accept a control signal of 4-20mA or 0-10Vdc compatible with BMS.

Output rating of 0.003-0.015 psi consuming 0.3 CFM maximum @ 20.0 psi supply.

Snap track mounted for panel applications or with an optional ABS enclosure.

Operating temperature range of 32˚F to 140˚F.

Male barb fittings for flexible tubing.

* + - 1. Air Quality Sensor - Wall Mounted
				1. Provide wall mounted air quality sensors as indicated within the Field termination schedules and/or control diagrams. Sensors shall meet, at minimum, the following requirements:

Measurement of volatile organic compounds (VOC) that could contain, at minimum, the following gases:

Methane

Ethylene

Hydrogen

Carbon Monoxide

Propane

Ammonia

Microprocessor-based using a semiconductor element based on the Taguchi gas principle.

White attractive ventilated cover.

20-30 Vac/dc power supply, 100mA @24Vdc, 220mA @24Vac, 6VA max.

Analog stepped output standard 0-10 Vdc or optional 4-20mA and adjustable relay.

Programming and selection via internal pushbuttons and jumpers.

Temperature range of 32˚F to 104˚F.

* + - 1. Air Quality Sensor - Duct Mounted
				1. Provide duct mounted air quality sensors as indicated within the field termination schedules and/or control diagrams. Sensors shall meet, at minimum, the following requirements:

Measurement of air stream volatile organic compounds (VOC) that could contain, at minimum, the following gases:

Methane

Ethylene

Hydrogen

Carbon Monoxide

Propane

Ammonia

Microprocessor-based using a semiconductor element based on the Taguchi gas principle.

20-30 Vac/dc power supply, 100mA @24Vdc, 220mA @24Vac, 6VA max.

Analog stepped output standard 0-10 Vdc or optional 4-20mA and adjustable relay.

Programming and selection via internal pushbuttons and jumpers.

Temperature range of 32˚F to 104˚F.

8" duct probe.

* + - 1. Carbon Dioxide (CO2) Sensor
				1. Provide a space or duct carbon dioxide gas detection sensor as indicated within the field termination schedules and/or control diagrams. Carbon dioxide detection sensors shall meet, at minimum, the following requirements:

Set-up to be fully microprocessor-based c/w LCD.

4-20 mA, 0-10 or 0-5 Vdc output compatible with BMS proportional to 0 to 2000 ppm of carbon dioxide concentration

Power supply to be 20-28Vac/dc @ 140 mA max for 24 Vac and 80 mA avg. @24 Vdc.

No maintenance or periodic sensor replacement needed. The sensor shall have a 5-year calibration interval, utilizing the Automatic Calibration Logic Program (ACLP).

Standard accuracy to be 3% of reading or 75 ppm, whichever is greater.

Optional integral humidity and temperature transmitter or temperature sensor (thermistor or RTD)

Optional setpoint adjustment, override switch and relay.

Operating temperature of 32˚F to 122˚F.

* + - 1. Carbon Monoxide (CO) Sensor
				1. Provide CO monitoring systems for the enclosed levels of the parking garage. Provide complete coverage of the enclosed levels of the parking garage and provide systems for each level. A CO monitoring system shall not cover an area on more than one level and the failure of any component shall not affect more than one level.

Sensors shall be of the electrochemical type.

Locate sensing points on walls and columns at 5 to 6.5 ft above floor level. Locate one sensing point per 7500 ft². Do not locate sensing points closer than 6.5 ft to traffic lanes.

Sensor range shall be of 0 to 300 ppm for 5% accuracy cell

Provide two (2) relay contacts, at minimum, per sensor, to indicate CO warning level (initially set at 50ppm) and CO alarm level (initially set at 200ppm) for each sensing point.

Unit shall be complete with 85 dB audible alarm and have visual output reading via an LCD display of the gas sensed.

Provide 4-20mA, 0-10 or 0-5Vdc output of Carbon Monoxide sensed compatible with BMS system.

The proposed sensor locations shall be submitted at the shop drawing stage and shall be amended as directed by the Owner and/or Engineer.

Sensor shall be factory calibrated and will only require calibration after a minimum one (1) year service.

* + - 1. Leak Detection Monitoring – Water
				1. Provide water leak monitoring as identified within the Field termination schedules and/or control diagrams. Water leak detection monitors shall meet, at minimum, the following requirements:

Corrosion and abrasion resistant.

Adjustable height-single point model

Configured for normally open or normally closed as required by the application.

Form C output relay rated at 5 amps @ 120 Vac / 30 Vdc.

Operating temperature range of -40˚F to 185˚F.

Optional remote mount probe and water sensing cable available in different lengths.

* + - 1. Ambient Light Level Sensor
				1. Provide ambient light level sensors as indicated within the field termination schedules and/or control diagrams. Light level sensor shall meet, at minimum, the following requirements:

Light sensor shall have a 12 – 35 Vdc power at maximum 22mA current draw.

4-20 mA output proportional to the ambient light level where 4 mA is light, and 20 mA is dark.

Photosensitive resistor with analog transducer.

Mounted on the exterior of a North wall on the roof.

Temperature range of -13˚F to 167˚F.

* 1. EXECUTION
		1. Installation of Sensors
			1. Install sensors according to manufacturer's recommendations.
			2. Mount sensors rigidly and adequately for operating environment.
			3. Install room temperature sensors on concealed junction boxes properly supported by wall framing.
			4. Air seal wires attached to sensors in their raceways or in the wall to prevent sensor readings from being affected by air transmitted from other areas.
			5. Use averaging sensors in mixing plenums and hot and cold decks. Install averaging sensors in a serpentine manner vertically across duct. Support each bend with a capillary clip.
			6. Install mixing plenum low-limit sensors in a serpentine manner horizontally across duct. Support each bend with a capillary clip. Provide 10 ft of sensing element for each 10 ft² of coil area.
			7. Install pipe-mounted temperature sensors in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.
			8. Install outdoor air temperature sensors on north wall at designated location with sun shield.
			9. Differential Air Static Pressure.
				1. Supply Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
				2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
				3. Building Static Pressure. Pipe pressure sensor's low-pressure port to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe high-pressure port to a location behind a thermostat cover.
				4. Piping to pressure transducer pressure ports shall contain a capped test port adjacent to transducer.
				5. Pressure transducers, except those controlling VAV boxes, shall be located in control panels, not on monitored equipment or on ductwork. Mount transducers in a vibration-free location accessible for service without use of ladders or special equipment.
				6. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before teeing for water gauges.
			10. Smoke detectors, high and low limit thermostats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset. Provide contacts that allow DDC software to monitor safety switch status.
		2. Flow Switch Installation
			1. Use correct paddle for pipe diameter.
			2. Adjust flow switch according to manufacturer's instructions.

End of Section

1. SECTION 23 09 13.33 BMS Control Valves
	1. GENERAL
		1. Related Sections
			1. SECTION 23 09 00, BMS Instrumentation and Control
			2. SECTION 23 09 13, BMS Instrumentation and Control Devices
			3. SECTION 23 09 13.13, BMS Actuators and Operators
			4. SECTION 23 09 13.23, BMS Sensors and Transmitters
			5. SECTION 23 09 13.43, BMS Control Dampers
			6. SECTION 23 09 23, BMS Direct Digital Control System
		2. References
			1. Refer to Section 23 09 00 - References
		3. Acronyms, Abbreviations, and Definitions
			1. Refer to Section 23 09 00 - Acronyms, Abbreviations, and Definitions
	2. PRODUCT
		1. Valves
			1. Unless otherwise indicated, hydronic system two and three-way automatic control valves shall be globe-style bodies and have the following characteristics:
				1. NPS 2 and Smaller: ANSI Class 250 bronze body, stainless steel stem, brass plug, bronze seat, and a TFE packing.
				2. NPS 2-½ and Larger: ANSI Class 125 cast iron body, stainless steel stem, bronze plug, bronze seat, and a TFE V-ring packing.
				3. Sizing:

Two-Position: Line size or size using a pressure differential of 1 psi.

2-way Modulating: 5 PSIG or twice the load pressure drop, whichever is greater.

3-way Modulating: Twice the load pressure drop, but not more than 5 PSIG.

* + - * 1. Flow Characteristics: 2-way valves shall have equal percentage characteristics; 3-way valves shall have linear characteristics.
				2. Close-off Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150% of total system head pressure for 2-way valves and 150% of the design pressure differential across the 3-way valves.
				3. Bodies for valves 3” to 6” shall be iron, cast iron or cast steel with flanged connections and shall be rated for ANSI Class 125 working pressure. Packing shall protect against leakage at the stem.
			1. Unless otherwise indicated, steam system globe-style vales shall have the following characteristics:
				1. NPS 2 and Smaller: ANSI Class 250 bronze body; stainless steel seat, stem and plug; and a TFE packing.
				2. NPS 2-½ and Larger: ANSI Class 125 [250] cast iron body; stainless steel seat, stem and plug; and a TFE V-ring packing.
				3. Sizing:

Two-Position: Line size or sized using 10% of inlet gauge pressure.

Modulating: 15 PSIG or less inlet steam pressure, the pressure drop shall be 80% of inlet gauge pressure. Higher than 15 PSIG inlet steam pressure the pressure drop shall be 42% of the inlet absolute pressure.

* + - * 1. Flow Characteristics: Linear or equal percentage characteristics.
				2. Close-off Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150% of operating (inlet) pressure.
			1. Where specified, ball-style body automatic control valves shall adhere to the following:
				1. NPS 3 and Smaller: Nickel-plated forged brass body rated at no less than 400 psi, stainless steel ball, and blowout proof stem, NPT female end fittings, with a dual EPDM O-ring packing design, fiberglass reinforced Teflon seats, and a Tefzel flow characterizing disc.
				2. Sizing:

Two-Position: Line size or size using a pressure differential of 1 psi.

2-way Modulating: 5 PSIG or twice the load pressure drop, whichever is greater.

3-way Modulating: Twice the load pressure drop, but not more than 5 PSIG.

* + - * 1. Close-off Pressure Rating: 100 psi. [NPS ¾” and Smaller for Terminal Units: 200 psi.]
				2. The actuator shall be the same manufacturer as the valve, integrally mounted to the valve at the factory with a single screw on a four-way DIN mounting-base.
				3. All control ball valves shall feature characterized flow guides when used for modulating applications.
			1. Where specified, butterfly control valves shall adhere to the following:
				1. NPS 2 to 12: Valve body shall be full lugged cast iron 200 PSIG body with a 304 stainless steel disc, EPDM seat, extended neck and shall meet ANSI Class 125/150 flange standards. Disc-to-stem connection shall utilize an internal spline. External mechanical methods to achieve this mechanical connection, such as pins or screws, are not acceptable. The shaft shall be supported at four locations by RPTFE bushings.
				2. NPS 14 and Larger: Valve body shall be full lugged cast iron 150 PSIG body with a 304 stainless steel disc, EPDM seat, extended neck and shall meet ANSI Class 125/150 flange standards. Disc-to-stem connection shall utilize a dual-pin method to prevent the disc from settling onto the liner. The shaft shall be supported at four locations by RPTFE bushings.
				3. Sizing:

Two-Position: Line size or size using a pressure differential of 1 psi.

Modulating: [5 psig] or twice the load pressure drop, whichever is greater. Size for the design flow with the disc in a 60° open-position with the design velocity less than 12 feet per second.

* + - * 1. Close-off Pressure Rating: NPS 2” to 12” 200 psi bubble-tight shutoff.
				2. NPS 14” and larger, 150 psi bubble-tight shut-off.
			1. Zone Valves (On/Off, Two-Position Applications):
				1. NPS 1 and Smaller: Forged brass body, rated at no less than 300 psi, female NPT union or sweat with a stainless-steel stem and EPDM seals.
				2. Sizing:

Two-Position: Line size or size using a pressure differential of 1 psi.

* + - * 1. Close-off Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150% of total system head pressure for 2-way valves and 125% of the design pressure differential across the 3-way valves.
				2. The actuator shall be the same manufacturer as the valve, integrally mounted to the valve at the factory.
	1. EXECUTION
		1. Co-ordination
			1. Coordinate delivery of control valves to site.
			2. Tag and mark valves for their purpose and location.
			3. Supervise Mechanical Contractor in the installation of the control valves ensuring proper valve(s) are located and installed in proper location(s)

End of Section

1. SECTION 23 09 13.43 BMS Control Dampers
	1. GENERAL
		1. Related Sections
			1. SECTION 23 09 00, BMS Instrumentation and Control
			2. SECTION 23 09 13, BMS Instrumentation and Control Devices
			3. SECTION 23 09 13.13, BMS Actuators and Operators
			4. SECTION 23 09 13.23, BMS Sensors and Transmitters
			5. SECTION 23 09 13.33, BMS Control Valves
			6. SECTION 23 09 23, BMS Direct Digital Control System
		2. References
			1. Refer to Section 23 09 00 - References
		3. Acronyms, Abbreviations, and Definitions
			1. Refer to Section 23 09 00 - Acronyms, Abbreviations, and Definitions
	2. PRODUCT
		1. Automatic Control Dampers
			1. Dampers shall be minimum leakage type to conserve energy and the temperature control manufacturer shall submit leakage data for all control dampers with the temperature control submittal.
			2. Damper leakage ratings shall be certified in accordance with AMCA Standard 500-D.
			3. Provide any automatic control dampers not specified to be integral with other equipment.
			4. Provide automatic control dampers as specified herein:
				1. Frame construction shall not be less than 14-gauge galvanized steel or extruded aluminum at a minimum 4-1/2” X 1” X 0.125” in thickness.
				2. Blades shall be single skin and not less than 16-gauge galvanized steel roll-formed or extruded aluminum. Blades shall not be over: 8” wide, 48” in length and 72” high.
				3. All blade edges and top and bottom of frame shall be provided with compressible seals. Side seals shall be compressible stainless steel of the tight-seal spring type.
				4. Blade seals shall provide for a maximum leakage rate of 10 CFM per square foot at 2.5 inches of WC differential pressure. Dampers and seals shall be suitable for temperature ranges of -40 to 180 ˚F.
				5. Bearings shall corrosion-resistant, molded synthetic sleeve type turning in an extruded hole in the damper frame.
				6. Axles shall be a minimum of ½” diameter and be welded to blade or riveted to blade
				7. Dampers shall be sized to meet flow requirements of the application. The sheet metal contractor shall furnish and install baffles to fit the damper to duct size. Baffles shall not exceed 6".
				8. Where ultra-low leakage dampers are specified the blade edges shall be fitted with replaceable, snap-on, inflatable seals to limit damper leakage to 6 CFM per square foot for dampers in excess of sixteen inches square at 1 inch of WC.
				9. Individual damper sections shall not be larger than 48” X 60”. Provide a minimum of one damper actuator per section.
				10. All proportional control dampers shall be opposed or parallel blade type as hereinafter specified and all two-position dampers shall be parallel blade types.
				11. Combination automatic smoke control dampers, where indicated on the plans, shall conform to the UL555S Leakage Class specified.
	3. EXECUTION
		1. Co-ordination
			1. Coordinate delivery of dampers to site.
			2. Tag and mark dampers for their purpose and location.
			3. Supervise Mechanical Contractor in the installation of the dampers ensuring proper dampers(s) are located and installed in proper location(s)

End of Section

1. SECTION 23 09 23 BMS Direct Digital Control System
	1. GENERAL
		1. Related Sections
			1. SECTION 23 09 00 BMS Instrumentation and Control
			2. SECTION 23 09 13, BMS Instrumentation and Control Devices
			3. SECTION 23 09 13.13, BMS Actuators and Operators
			4. SECTION 23 09 13.23, BMS Sensors and Transmitters
			5. SECTION 23 09 13.33, BMS Control Valves
			6. SECTION 23 09 13.43, BMS Control Dampers
		2. References
			1. Supplementing 23 09 00 1.2 References requirements.
				1. ANSI/ASHRAE 135-2016, BACnet - A Data Communication Protocol for Building Automation and Control Networks.
		3. Acronyms, Abbreviations, and Definitions
			1. Supplementing 23 09 00 1.3 Acronyms, Abbreviations and Definitions requirements
				1. Acronyms used in BMS.

AI - Analog Input

AO - Analog Output

BACnet® - Building Automation and Control Network

BMS - Building Management System

CAD - Computer-Aided Design

CDL - Control Description Logic

COSV - Change of State or Value

CPU - Central Processing Unit

DI - Digital Input

DO - Digital Output

ECU - Equipment Control Unit

IDE - Interface Device Equipment

LAN - Local Area Network

NCU - Network Control Unit

ASPECT – Software framework for building device-to-enterprise applications and Internet-enabled products.

OS - Operating System

OWS - Operator Work Station

PC - Personal Computer

PCI - Peripheral Control Interface

PCMCIA - Personal Computer Micro Card Interface Adapter

RAM - Random Access Memory

ROM - Read-Only Memory

FCU - Terminal Control Unit

USB - Universal Serial Bus

UPS - Uninterruptible Power Supply

* + - 1. Definitions:
				1. Point: a point may be logical or physical. Logical points are values calculated by system such as totals, counts, derived corrections i.e. as result of and/or statements in CDL's. Physical points are inputs or outputs, which have hardware, wired to controllers which are measuring or providing status conditions of contacts or relays providing interaction with related equipment (stop, start) or valve or damper actuators.
			2. Symbols and Engineering unit abbreviations utilized in displays: to ANSI/ISAS 5.5.
				1. Printouts: to ANSI/IEEE 260.
		1. BMS Contractor Qualifications
			1. Supplementing 23 09 00 1.12 BMS Contractor Qualifications.
				1. The contractor must be regularly engaged in the service and installation of BACnet and ABB Cylon® ASPECT or ABB Cylon® INTEGRA as specified herein,

The Contractor shall have a minimum of 3 years’ experience in the sales, installation, engineering, programming servicing and of ABB Cylon® Products.

* + - * 1. The Contractor must be an authorized factory direct representative in good standing of the manufacturer of the proposed hardware and software components. Provide a letter dated within the last 12 months, from the manufacturer certifying that the Contractor is an authorized factory direct representative.
				2. The Contractor shall have a minimum of three (3) technicians who have completed the factory authorized training of the proposed manufactures hardware and software components and have completed ASPECT certification course(s).

Contractor must provide proof of required training.

The Contractor’s capabilities shall include engineering and design of control systems, programming, electrical installation of control systems, troubling shooting and service.

* + - * 1. The contractor shall submit a list of no less than three (3) similar (in function, application, and design) projects, which have similar Building Automation Systems as specified herein installed by the Contractor.

These projects must be on-line and functional such that the Owner’s/User’s representative can observe the system in full operation.

* + 1. General Description
			1. Supplementing 23 09 00 1.5 General Description requirements.
				1. System to be “Open Protocol”.

BACnet communications will be used for communications.

* + - * 1. Work covered by sections referred to above consists of fully operational BMS, including, but not limited to, following:

Building Controllers NCU, FCU.

OWS.

Data communications equipment necessary to achieve a BMS data transmission system including LAN hardware and software for a BACnet system.

Software complete with full documentation for software and equipment.

* + 1. Work Included
			1. Supplementing 23 09 00 Work Included requirements.
			2. Provide a new Building Management System to control and monitor the building’s mechanical and electrical systems.
				1. The system installed shall seamlessly connect devices other than HVAC throughout the building regardless of subsystem type, i.e. HVAC, lighting, and security devices should easily coexist on the same network channel without the need for gateways.
				2. Components not supplied by the primary manufacturer shall be integrated to share common software for network communications, time scheduling, alarm handling, and history logging.
			3. The Installer furnishing the BMS network shall meet with the Installer(s) furnishing each of the following products to coordinate details of the interface between these products and the DDC network.
				1. The variable frequency drive (VFD) vendor shall furnish VFDs with an interface to the control and monitoring points specified utilizing:

BACnet/IP network connection.

BACnet MS/TP network connection

Modbus TCP network connection

Modbus RTU network connection

* + - * 1. Energy and utility metering shall interface to the BMS system and provide the monitoring points specified herein utilizing:

BACnet network connection.

Modbus network connection

* + - * 1. The lighting control vendor shall furnish lighting controls with an interface to the control and monitoring points specified utilizing:

BACnet/IP network connection

* + - * 1. The Owner or his designated representative shall be present at this meeting.
				2. Each Installer shall provide the Owner and all other Installers with details of the proposed interface, hardware and software identifiers for the interface points, network identifiers, wiring requirements, communication speeds, and required network accessories.
				3. The purpose of this meeting shall be to ensure there are no unresolved issues regarding the integration of these products into the BMS network.
				4. Submittals for these products shall not be approved before the completion of this meeting.
			1. Provide new controllers of the latest revisions with input and output points as specified herein.
			2. Operator workstations located as listed in the specifications.
			3. Furnish and install all controllers to achieve system operation, any control devices, conduit, and wiring, in the facility as required to provide the operation specified.
			4. Furnish and load all software required to implement a complete and operational BMS.
		1. System Design Responsibility
			1. Supplementing 23 09 00 1.13 System Design Responsibility requirements.
				1. Supply sufficient programmable controllers of all types to meet project requirements. Quantity and points contents to be approved by Owner before installation.

Field Control Units (FCU) shall be utilized for primary mechanical and electrical systems such as Air handling equipment, Make-up Air Unit, Boiler System Control, and Chiller System Control type of applications.

Field Control Units (FCU) shall be utilized for terminal equipment, such as Variable Air Volume, Fan Coil, Heat Pump, Roof Top, and Chilled Ceiling type of applications.

Each NCU and each LAN shall have the capability of accepting 20% additional FCU(s) without the necessity of adding additional LAN controllers or LAN wiring.

The FCU controller programming or configuration tools (see section 23 09 13 FCU Programming Software) shall be fully accessible through the Operator Workstation and Web Browser Client.

* + - * 1. Regardless of the maximum number of controllers recommended by the manufacturer, it is ultimately the exclusive responsibility of the systems integrator/building controls contractor to ensure that the NCU has adequate resources for the number of controllers attached to it.
				2. ASPECT® Enterprise Server software shall be furnished and installed on a server-grade PC for applications requiring two or more NCUs.
		1. Building Management System (BMS)
			1. The contractor shall be responsible for the hardware and software for the enterprise framework and system integration required for the complete Building Management System.
			2. The BMS shall be comprised of Network Control Units (NCU) connected to the Building Management System local area network (BMS LAN).
				1. Access to the BMS, either through a Workstation on the BMS LAN, within the building or through a Wireless Application Protocol device, or remotely through the Internet, shall be accomplished through a standard Web browser.
				2. Each NCU shall communicate to BTL Listed BACnet controllers provided under the Programmable Controllers section.
			3. The system includes software and programming of the NCU(s), Operator Workstation(s) (OWS) software and hardware, development of all graphical screens, setup of schedules, trends, logs and alarms, network management and connection of the NCU(s) to the local area network.
		2. System Design
			1. The system shall consist of a network of Network Control Units (NCUs), interoperable Field Control Units (FCUs). All controllers for terminal units, air handling units (AHU) and controllers shall communicate and share data, utilizing BACnet communications protocols only.
			2. This specification intends to provide a distributed and networked open Building Management System, the capability to integrate ANSI/ASHRAE Standard 135, BACnet and ISO/IEC 14908-1: Open Data Communication in Building Automation, Controls and Building Management – Control Network Protocol into a unified system to provide flexibility for expansion, maintenance, and service of the system.
			3. The proposed system must maintain strict adherence to industry standards including ANSI/ASHRAE Standard 135, and Device Profile to assure interoperability between all system components. BACnet system must be tested and listed on the BACnet Testing Laboratory (BTL) web site. Systems based on vendor-specific proprietary hardware or software will not be considered for this project.
			4. Systems utilizing gateways to proprietary communication systems will not be considered for this project. A gateway is considered to be a device or controller where the sole function is mapping of data points from one protocol to another. A gateway device cannot perform higher-level energy management functions such as Outdoor Air Optimization, Electrical Demand Limiting and the like.
			5. The supplied system software shall employ object-oriented technology (OOT) for the representation of all data and control devices within the system. Also, adherence to industry standards including ANSI/ASHRAE Standard 135, BACnet to assure interoperability between all system components is required.
			6. A hierarchical topology is required to assure reasonable system response times and to manage the flow and sharing of data without unduly burdening the customer’s internal Intranet network. Systems employing a flat single-tiered architecture shall not be acceptable. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 10 seconds for network-connected user interfaces. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the point of annunciation shall not exceed 60 seconds for remote or dial-up connected user interfaces.
			7. User Access
				1. The supplied system must incorporate the ability to access all data using standard Web browsers without requiring proprietary operator interface and configuration programs.
			8. An Open Database Connectivity (ODBC) or Structured Query Language (SQL or SQL Lite) compliant server database is required for all system databases, all controller program graphics and network databases which shall be provided in an ASPECT or INTEGRA system format.
				1. This data shall reside on a supplier-installed server for all database access.
				2. Systems requiring proprietary database and user interface programs shall not be acceptable.
			9. Software Tools
				1. All software tools needed for full functional use, including programming of controllers, ASPECT or INTEGRA network management and expansion, and graphical user interface to be used in the development of the BMS described within these specifications, shall be provided to the owner or his designated agent.

Any licensing required by the manufacturer now and to the completion of the warranty period, including changes to the licensee of the software tools and the addition of hardware corresponding to the licenses, to allow for a complete and operational system for both normal day to day operation and servicing shall be provided.

Any such changes to the designated license holders shall be made by the manufacturer upon written request by the owner or his agent.

Any cost associated with the license changes shall be identified within the BMS submittals.

* + - 1. Software License Agreement
				1. The Owner shall sign a copy of the manufacturer's standard software and firmware licensing agreement as a condition of this contract.
				2. Such license shall grant use of all programs and application software to Owner as defined by the manufacturer's license agreement but shall protect manufacturer's rights to disclosure of trade secrets contained within such software.

The Owner shall be the named license holder of all software associated with any and all incremental work on the project(s).

Also, the Owner shall receive ownership of all job-specific configuration documentation, data files, and application-level software developed for the project.

This shall include all custom, job-specific software code, databases, and documentation for all configuration and programming that is generated for a given project and/or configured for use with the NCU, Server, OWS, and any related LAN/WAN/Intranet and Internet-connected routers and devices.

All required User IDs and passwords for access to any component or software program shall be provided to the owner.

* + 1. Dynamic Data Access
			1. All operator devices, either network resident or connected via dial-up modems, shall have the ability to access all point status and application report data or execute control functions for all other devices via the local area network. Access to data shall be based upon logical identification of building equipment.
		2. Networks
			1. The BMS network(s) must be based on Standardized Protocols and Systems.
			2. ASPECT shall be used at the network levels as the manager(s).
			3. High-speed data transfer rates for alarm reporting, quick report generation form multiple controllers and upload/download efficiency between network devices.
			4. Support of any combination of controllers and operator workstations directly connected to the local area network. A minimum of 50 devices shall be supported on a single local area network.
			5. Detection and accommodation of single or multiple failures of workstations, controller panels, and the network media. The network shall include provisions for automatically reconfiguring itself to allow all operational equipment to perform their designated functions as effectively as possible in the event of single or multiple failures.
			6. Message and alarm buffering to prevent information from being lost.
			7. Error detection, correction, and retransmission to guarantee data integrity.
			8. Default device definition to prevent loss of alarms or data, and ensure alarms are reported as quickly as possible in the event an operator device does not respond.
			9. Commonly available, multiple sourced, networking components shall be used to allow the system to coexist with other networking applications such as office automation. Ethernet to IEEE 802.3 standard is the only acceptable technology.
			10. Synchronization of the real-time clocks in all NCU panels shall be provided.
			11. The BMS LAN shall be a 100 Megabits/sec Ethernet network supporting BACnet, Java, XML, HTTP, SOAP, OBIX, SNMP and SMTP Protocols for maximum flexibility for integration of building data with enterprise information systems and providing support for multiple Network Control Units (NCUs), user workstations and where specified, a local server. Local area network minimum physical and media access requirements:
				1. Ethernet; IEEE standard 802.3
				2. Cable; 100 Base-T, UTP-8 wire, category 5
				3. Minimum throughput; 100 Mbps
				4. Provide access to the BMS LAN via a Wireless Application Protocol (WAP) device. Through this connection, the BMS LAN will provide authorized staff with the ability to monitor and control the BMS from any location within the through a web browser, or web-enabled devices.
				5. Provide access to the BMS LAN from a remote location, via the Intranet or Internet. The owner shall provide a secure VPN connection to the Internet to enable access via high-speed cable modem, asynchronous digital subscriber line (ADSL) modem, ISDN line, T1 Line or access to an Internet Service Provider (ISP). If required, the owner will provide a switch/firewall between the building LAN and the BMS LAN. Through this connection, the BMS LAN will provide authorized staff with the ability to monitor and control the BMS from a remote location through a web browser, or web-enabled devices.
			12. Controller Local Area Network (BMS sub LAN)
				1. Provide a network of stand-alone, distributed direct digital controllers that operate on the following protocol using the specified physical layers:

Controllers using proprietary protocols or protocols other than listed herein are unacceptable.

* + - * 1. The design of the BMS sub LAN shall network Field Control Units (FCU) to a Network Control Unit (NCU).
				2. This level of communication shall support a family of application-specific controllers and shall communicate bi-directionally with the network through DDC Controllers for transmission of global data.
				3. Field Control Unit (FCU) shall be arranged on the BMS sub-LAN's in a functional relationship manner with Network Control Unit (NCU). Ensure that a Variable Air Volume (VAV) Terminal Control Unit (FCU) is logically on the same LAN or segment as the its corresponding Air Handling Unit (AHU).
	1. PRODUCTS
		1. Quality Assurance
			1. Supplementing 23 09 00 2.1 Quality Assurance requirements.
				1. The manufacturer of the Building Management System digital controllers shall provide documentation supporting compliance with ISO 9001:2000 (Model for Quality Assurance in Design/Development, Production, Installation and Servicing).
				2. Provide a copy of the registration certificate that contains the ISO 9001:2000 Certification bearing the name of the registered auditor.
				3. Control products such as direct digital controllers, control valves, actuators, sensors, and transmitters shall be provided from a single manufacturer.

Provide product literature that bears the name of the manufacturer on all direct digital controllers, control valves, actuators, sensors, and transmitters.

* + - * 1. Provide satisfactory operation without damage at 110% above and 85% below rated voltage and 3-hertz variation in line frequency. Provide static, transient, and short circuit protection on all inputs and outputs. Communication lines shall be protected against incorrect wiring, static transients and induced magnetic interference. Bus connected devices shall be AC coupled, or equivalent so that any single device failure will not disrupt or halt bus communication.
				2. All controllers provided as part of this system and used for indoor applications shall operate under ambient environmental conditions of 32 ˚F to 122 ˚F dry bulb and 5% to 90% relative humidity, non-condensing as a minimum.
				3. All controllers provided as part of this system and used for outdoor applications shall operate under ambient environmental conditions of -40 ˚F to 158 ˚F dry bulb and 5% to 90% relative humidity, non-condensing as a minimum.
		1. Acceptable System Manufacturers
			1. Provide a Building Management System supplied by a company regularly engaged in the manufacturing and distribution of building automation systems. The BMS Manufacturer shall meet the following qualifications as a minimum:
				1. The manufacturer of the hardware and software components must be primarily engaged in the manufacture of building automation systems as specified herein and must have been so for a minimum of five (5) years.
				2. The manufacturer of the hardware and software components, as well as its subsidiaries, must be a member in good standing of the BACnet International.
				3. At least 75% of the manufactured product line shall be produced under their direction, including R&D and assembly. Rebranding of another manufactured product shall not qualify.
			2. The manufacturer of the hardware and software components shall have a technical support group accessible via a toll-free number that is staffed with qualified personnel, capable of providing instruction and technical support service for networked control systems.
			3. Acceptable Manufacturers
				1. ABB Cylon® Controls as provided by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
			4. If a manufacturer or vendor, other than those listed in ‘.3 Acceptable Manufacturers’ wishes to seek equivalency to any of the above controls offerings, then the manufacturer or vendor will be subject to the original pre-qualification criteria that were used to qualify the ‘Acceptable Manufacturers’. Failure to meet the qualifications will render the proposed solution by such a manufacturer or vendor as ineligible.
	1. EXECUTION
		1. Preliminary Design Review
			1. Supplementing 23 09 00 3.8 Preliminary Design Review requirements.
				1. The BMS contractor shall submit a preliminary design document for review. This document shall contain the following information in addition to the requirements of 23 09 00:

Provide product brochures and a technical description of the Server, Operator Workstation, and Network Control Unit (NCU) software required to meet this specification. Provide a description of software programs included.

Open Protocols - For all direct digital controller hardware BACnet Protocol Implementation Conformance Statement PICS. Provide a complete description and documentation of any proprietary services and/or objects where used in the system.

Provide a description and samples of Operator Workstation graphics and reports.

Provide a URL address for the engineer to view the proposed functionality via a web-based BMS through a standard web browser.

* + 1. Submittals
			1. Supplementing 23 09 00 3.9 Submittals requirements.
				1. Control System Shop Drawings

Detailed system architecture and points list showing all points (including all spare points at each controller) associated with each controller, controller locations, and describing the sequence of operation of each piece of equipment.

* + - * 1. Direct Digital Control System Hardware

Bill of materials indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.

Manufacturer's description and technical data such including product specifications and installation and maintenance instructions for items listed herein:

Direct digital controllers (BACnet/IP and BACnet MS/TP)

Sensors and Transmitters

Transducers

Actuators

Automatic Control Valves

Automatic Control Dampers

Air Flow Stations

Control panels

Operator interface equipment

Ancillary equipment such as relays, power supplies and wiring

Riser diagrams showing control network layout, communication protocol, and wire types.

* + - * 1. Building Management System Server and Operator Workstation (OWS)

Complete bill of material indicating quantity, manufacturer, model number, and relevant technical data of equipment used.

Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:

Central Processing Unit (CPU) or web server

Monitors

Keyboards

Uninterruptible Power supplies

Network switches, hubs, and routers.

Interface equipment between CPU or server and control panels

Operating System software

Operator interface software

Color graphic software

Third-party software

Network diagram of control, communication, and power wiring for BMS Server and OWS installation.

End of Section

1. SECTION 23 09 33 Variable Frequency Drives
	1. GENERAL
		1. DESCRIPTION
			1. This specification is to cover a complete Variable Frequency Drive (VFD) consisting of a pulse width modulated (PWM) inverter designed for use with both asynchronous and permanent magnet motors.
			2. The drive manufacturer shall supply the drive and all necessary options as specified. All drives installed on this project shall be from the same manufacturer and have a common user interface (control panel). The manufacturer shall have been engaged in the production of this type of equipment for a minimum of 30 years. Drives that are manufactured by a third party and “brand labeled” shall not be acceptable. Drive manufacturers who do not build their own power boards and assemblies, or do not have full control of the power board manufacturing and quality control, shall be considered as a “brand labeled” drive.
			3. This specification is intended to supplement a drive schedule. The drive schedule identifies the optimized BOM for the project and includes quantity, size, voltage, enclosure rating, options, and harmonic mitigation requirements of the drives. IEEE 519-2014 is an electrical system standard for harmonic mitigation and not intended to be applied to an individual piece of equipment. Drives are only one of many sources of harmonics, thus verification of system IEEE 519-2014 compliance is beyond the VFD manufacturer’s scope. The EOR (Engineer of Record) is responsible for conducting an electrical system study and verifying the drive schedule has specified proper harmonic mitigation for the drives.
		2. QUALITY ASSURANCE
			1. Referenced Standards and Guidelines:
				1. Institute of Electrical and Electronic Engineers (IEEE)

IEEE 519-2014, IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

* + - * 1. Underwriters Laboratories (as appropriate)

UL 508, 508A, 508C

UL 61800, 61800-5-1, 61800-5-2

UL 1995

* + - * 1. The Association of Electrical Equipment and Medical Imaging Manufacturers (NEMA)

NEMA ICS 7-2014, Adjustable Speed Drives

* + - * 1. International Electrotechnical Commission (IEC)

EN/IEC 61800

* + - * 1. National Electric Code (NEC)

NEC 430.120, Adjustable-Speed Drive Systems

* + - * 1. CSA Group

CSA C22.2 No. 274

* + - * 1. International Building Code (IBC)

IBC 2018 Seismic – referencing ASCE 7-16 and ICC AC-156

* + - 1. Qualifications:
				1. Drives shall be UL labeled as a complete assembly. The base VFD shall be UL listed for 100 kA SCCR when installed in accordance with the manufacturer’s guidelines.
				2. CE Mark – The base drive shall conform to the European Union Electromagnetic Compatibility directive, a requirement for CE marking. The base drive shall meet product standard EN 61800-3 for the First Environment restricted distribution (Category C2).
				3. The base drive shall be seismically certified and labeled as such in accordance with the 2018 International Building Code (IBC):

Seismic importance factor of 1.5, and minimum 2.5 SDS rating is required.

Ratings shall be based upon actual shake test data as defined by ICC AC-156, via all three axis of motion.

Seismic certification of equipment and components shall be provided by OSHPD preapproval.

* + - * 1. The base drive shall be SEMI-F47 certified. The drive must tolerate voltage sags to 50% for up to 0.2 seconds, sags to 70% for up to 0.5 seconds, and sags to 80% for up to one second.
				2. Acceptable Manufacturers

ABB ACH Series.

Alternate manufacturer’s requests shall be submitted in writing to the Engineer for approval at least 20 working days prior to bid. Approval does not relieve the supplier of specification requirements.

* + 1. SUBMITTALS
			1. Submittals shall include the following information:
				1. Outline dimensions, conduit entry locations and weights.
				2. Customer connection and power wiring diagrams.
				3. OSHPD preapproval, seismic certification and installation requirements where applicable.
				4. Complete technical product description with complete list of options provided. Any portions of this specification not met must be clearly indicated or the supplier and contractor shall be liable to provide all additional components required to meet this specification.
				5. Building Information Modeling (BIM) objects shall be available online.
	1. PRODUCTS
		1. VARIABLE FREQUENCY DRIVES
			1. The drive package as specified herein and defined on the drive schedule shall be enclosed in a UL Type enclosure (enclosures with only NEMA ratings are not acceptable), completely assembled and tested by the manufacturer to ISO9001 standards.
			2. The drive shall provide full rated output from a line of +10% to -15% of nominal voltage. The drive shall continue to operate without faulting from a line of +25% to -35% of nominal voltage.
				1. Drives shall be capable of continuous full load operation under the following environmental operating conditions:

Ambient temperature -15 to 40° C (5 to 104° F).

Altitude 0 to 1000 m (0 to 3,300 ft) above sea level.

Humidity 5 to 95%, non-condensing.

* + - 1. All drives shall utilize the same Advanced Control Panel (keypad) user interface.
				1. Plain English text

The display shall be in complete English words for programming and fault diagnostics (alpha-numeric codes are not acceptable).

Safety interlock and run permissive status shall be displayed using predetermined application specific nomenclature, such as: Damper end switch, smoke alarm, vibration trip, and overpressure.

Safety interlock, run permissive, and external fault status shall have the option of additional customized project specific terms, such as: AHU-1 End Switch, Office Smoke Alarm, CT-2 Vibration.

* + - * 1. The control panel shall include at minimum the followings controls:

Four navigation keys (Up, Down, Left, Right) and two soft keys to simplify operation and programming.

Hand-Off-Auto selections and manual speed control without having to navigate to a parameter.

Fault Reset and Help keys. The Help key shall include assistance for programming and troubleshooting.

* + - * 1. Multiple Home View screens shall be capable of displaying up to 21 points of information. Customizable modules shall include bar charts, graphs, meters, and data lists. Displays shall provide real time graphical trending of output power, frequency, and current within selectable intervals of 15/30/60 minutes and 24 hours.
				2. The control panel shall display the following items on a single screen; output frequency, output current, reference signal, drive name, time, and operating mode (Hand vs Auto, Run vs Stop). Bi-color (red/green) status LED shall be included. Drive (equipment) name shall be customizable.
				3. There shall be a built-in time clock in the control panel. The clock shall have a battery backup with 10 years minimum life span. Daylight savings time shall be selectable.
				4. I/O Summary display with a single screen shall indicate and provide:

The status/values of all analog inputs, analog outputs, digital inputs, and relay outputs. Drives that require access to internal or live components to measure these values, are not acceptable.

The programmed function of all analog inputs, analog outputs, digital inputs, and relay outputs.

The ability to force individual digital I/O high or low and individual analog I/O to desired value, for increased personal protection during drive commissioning and troubleshooting. Drives that require access to internal or live components to perform these functions, are not acceptable.

* + - * 1. The drive shall automatically backup parameters to the control panel. In addition to the automatic backup, the drive shall allow two additional unique backup parameter sets to be stored. Backup files shall include a time and date stamp. In the event of a drive failure, the control panel of the original drive can be installed on the replacement drive, and parameters from that control panel can be downloaded into the replacement drive.
				2. The control panel shall display local technical support contact information as part of drive fault status.
				3. The control panel shall be removable, capable of remote mounting.
				4. The control panel shall have the ability to store screen shots, which are downloadable via USB.
				5. The control panel shall have the ability to display a QR code for quick access to drive information.
				6. The LCD screen shall be backlit with the ability to adjust the screen brightness and contrast, with inverted contrast mode. A user-selectable timer shall dim the display and save power when not in use.
				7. The control panel shall include assistants specifically designed to facilitate start-up. Assistants shall include: First Start Assistant, Basic Operation, Basic Control, and PID Assistant.
				8. Primary settings for HVAC shall provide quick set-up of all parameters and customer interfaces to reduce programming time.
				9. The drive shall be able to operate with the control panel removed.
				10. The drive shall be able to support a Bluetooth Advanced Control Panel. The Bluetooth control panel shall be FCC and QDL (Qualified Design Listing) certified.

A free app (iOS and Android) shall replicate the control panel on a mobile device or tablet. The control panel’s programming and control functionality shall function on the device. Customizing text, such as AHU-1 End Switch, shall be supported by the device’s keyboard.

Bluetooth connectivity shall allow uploading, downloading, and emailing of parameter sets.

Bluetooth connectivity shall include two pairing modes: Always discoverable with a fixed passcode, and manual discovery with a unique generated passcode every pairing.

The Bluetooth antenna shall be in the control panel. Antennas that are integrated in the drive’s control board, must include an external antenna, on all drives mounted inside cabinets.

Bluetooth connectivity shall be capable of being switched off.

* + - 1. All drives shall have the following hardware features/characteristics as standard:
				1. Two (2) programmable analog inputs shall accept current or voltage signals. Current or Voltage selection configured via control panel. Drives that require access to internal components to perform these functions, are not acceptable.
				2. Two (2) programmable analog outputs. At least one of the analog outputs shall be adjustable for current or voltage signal, configured via control panel. Drives that require access to internal components to perform these functions, are not acceptable.
				3. Six (6) programmable digital inputs. All digital inputs shall be programmable to support both active high and active low logic, and shall include adjustable on/off time delays. The digital input shall be capable of accepting both 24 VDC and 24 VAC.
				4. Three (3) programmable Form-C relay outputs. The relay outputs shall include programmable on/off time delays. The relays shall be rated for a continuous current rating of 2 Amps. Maximum switching voltage of 250 VAC / 30 VDC. Open collector and Form-A relays are not acceptable. Drives that have less than (3) Form-C relay outputs shall provide an option card to provide additional relay outputs.
				5. Drive terminal blocks shall be color coded for easy identification of function.
				6. The drive shall include an isolated USB port for interface between the drive and a laptop. A non-isolated USB port is not acceptable.
				7. An auxiliary power supply rated at 24 VDC, 250 mA shall be included.
				8. At a minimum, the drives shall have internal impedance equivalent to 5% to reduce the harmonics to the power line. 5% impedance may be from dual (positive and negative DC link) chokes, or AC line reactor. Drives with only one DC link choke shall add an AC line choke integral to the drive enclosure. Reference the drive schedule to determine if additional harmonic mitigation is required for the system to comply with IEEE 519-2014.
				9. The drive shall have cooling fans that are designed for field replacement. The primary cooling fan shall operate only when required and be variable speed for increased longevity and lower noise levels. Drives whose primary cooling fans are not variable speed, shall include a spare cooling fan.
				10. The overload rating of the drive shall be 110% of its normal duty current rating for 1 minute every 10 minutes, 130% overload for 2 seconds every minute. The minimum current rating shall meet or exceed the values in the NEC/UL table 430.250 for 4-pole motors.
				11. The input current rating of the drive shall not be greater than the output current rating. Per NFPA 70 430.122, drives with higher input current ratings may require the upstream wiring, protection devices, and source transformers to be upsized.
				12. Circuit boards shall be coated per IEC 60721-3-3; Chemical gasses Class 3C2 and Solid particles Class 3S2.
				13. Earth (ground) fault detection shall function in both modulating (running) and non-modulating modes.
				14. Coordinated AC transient surge protection system consisting of 4 MOVs (phase-to-phase and phase-to-ground), a capacitor clamp, and internal chokes. The MOVs shall comply with UL 1449 4th Edition. Drives that do not include coordinated AC transient surge protection shall include an external TVSS/SPD (Transient Voltage Surge Suppressor/Surge Protection Device).
				15. The drive shall include a robust DC bus to provide short term power-loss ride through. The DC bus Joule to drive kVA ratio shall be 4.5 J/kVA or higher. An inertia-based ride through function should help maintain the DC bus voltage during power loss events. Drives with control power ride through only, are not acceptable.
			2. All drives shall have the following software features as standard:
				1. A Fault Logger that stores the last 16 faults in non-volatile memory.

The most recent 5 faults save at least 9 data points, including but not limited to: Time/date, frequency, DC bus voltage, motor current, DI status, temperature, and status words.

The date and time of each fault and fault reset attempt shall be stored in the Fault Logger.

* + - * 1. An Event Logger that stores the last 16 warnings or events that occurred, in non-volatile memory.

Events shall include, but not limited to: Warning messages, checksum mismatch, run permissive open, start interlock open, and automatic reset of a fault.

The date and time of each event’s start and completion points shall be stored in the Event Logger.

* + - * 1. Programmable start method. Start method shall be selectable based on the application: Flying-start, Normal-start, and Brake-on-start.
				2. Programmable loss-of-load (broken belt / coupling) indication. Indication shall be selectable as a control panel warning, relay output, or over network communications. This function to include a programmable time delay to eliminate false loss-of-load indications.
				3. Motor heating function to prevent condensation build up in the motor. Motor heating adjustment, via parameter, shall be in “Watts.” Heating functions based only on “percent current” are not acceptable.
				4. Advanced power metering abilities shall be included in the drive. Drives without these data points, must include a separate power meter with each drive.

Instantaneous output power (kW)

Total power, broken down by kWh, MWh, and GWh units of measurement. Power meters that only display kWh and roll over or “max out” once the maximum kWh value is reached, are not acceptable. There shall be resettable and non-resettable total power meters within the drive.

Time based kWh metering for: current hour, previous hour, current day, and previous day.

Energy saving calculation shall be included that shows the energy and dollars saved by the drive.

* + - * 1. The drive shall include a motor flux optimization circuit that will automatically reduce applied motor voltage to the motor to optimize energy consumption and reduce audible motor noise.
				2. Run permissive circuit - There shall be a run permissive circuit for damper or valve control. Regardless of the source of a run command, the Drives shall provide a dry contact closure that will signal the damper to open. When the damper is fully open, an end-switch shall close, allowing the drive to run the motor.

The drive shall also include a programmable start delay, for when an end-switch is not provided.

* + - * 1. Start interlock circuit - Four separate start interlock (safety) inputs shall be provided. When any safety is opened, the motor shall be commanded to stop. The control panel will display the specific safety(s) that are open. The status of each safety shall be transmitted over the network communications. Wiring multiple safeties in series is not acceptable.
				2. External fault circuit – Three separate external fault inputs shall be provided. This circuit shall have the same features and functionality as the start interlock circuit, except it shall require a manual reset before the drive is allowed to operate the motor.
				3. The drive shall include a switching frequency control circuit that reduces the switching frequency based on actual drive temperature, and allows higher switching frequency settings without derating the drive. It shall be possible to set a minimum and a target switching frequency.
				4. Visual function block adaptive programming allowing custom control schemes, minimizing the need for external controllers. I.e. cooling tower staging logic. A free software tool shall be used to configure adaptive programming.
				5. The ability to automatically restart after an over-current, over-voltage, under-voltage, external fault, or loss of input signal protective trip. The number of restart attempts, trial time, and time between attempts shall be programmable. Each of these faults may have automatic restart individually disabled via a parameter selection.
				6. Three (3) programmable critical frequency lockout ranges to prevent the drive from operating the load continuously at an unstable speed/load.
				7. Seven (7) programmable preset frequencies/speeds.
				8. Two independently adjustable accel and decel ramps with 1 – 1800 seconds adjustable time ramps.
				9. PID functionality shall be included in the drive.

Programmable “Sleep” and “Wake up” functions to allow the drive to be started and stopped based on the level of a process feedback signal.

The drive shall include an independent PID loop for customer use, assigned to an Analog Output. This PID loop may be used for cooling tower bypass valve control, chilled water valve, etc.

* + - * 1. At least 4 parameter user sets that can be saved to the permanent memory and recalled using a digital input, timed function, or supervision function.
				2. Drive shall be compatible with an accessory that allows the control board to be powered from an external 24 VDC/VAC source, allowing the drive control to remain powered by a UPS during an extended power outage.
				3. A computer-based software tool shall be available to allow a laptop to program the drive. The drive shall be able to support programming without the need for line voltage. All necessary power shall be sourced via the laptop USB port.
				4. The drive shall include a fireman’s override mode. Upon receipt of a contact closure from the Fire Alarm Life Safety system, the drive shall operate in a dedicated Override mode distinct and separate from the drive’s Normal operation mode. The following features will be available in the drive override function:

The Override mode shall be secured by password to prevent changes once programmed.

The drive shall ignore external inputs and commands not defined as part of the override function.

Override operation mode shall be selectable between: single frequency, multiple fixed frequencies, follow an analog input signal, PID control, or come to a forced stop.

High priority safeties shall stop the drive and lower priority safeties shall be ignored in Override mode.

Drive faults shall be defined in Critical and Low priority groups. Critical faults shall stop the drive. Low priority faults shall be reset. Reset trials and timing shall be programmable.

The drive shall be configurable to receive from 1 to 3 discrete digital input signals and operate at up to three discrete speeds.

* + - * 1. The drive shall have multi-pump functionality and an intelligent master/follower configuration for controlling up to 8 parallel pumps equipped with drives. The drive shall have a parameter synchronization feature to program the PID, multi-pump, and AI parameters in all parallel drives. The functionality to start and stop the pumps based on capacity, operating time or efficiency of the pump to ensure each pump is operated regularly.

The multi-pump functionality shall control:

Flow Control

Pressure Control

Pump Alternation

* + - 1. Security Features
				1. The drive manufacture shall clearly define cybersecurity capabilities for their products.
				2. The drive shall include password protection against parameter changes.

There shall be multiple levels of password protection including: End User, Service, Advanced, and Override.

The drive shall support a customer generated unique password between 0 and 99,999,999.

The drive shall log an event whenever the drive password has been entered.

The drive shall provide a security selection that prevents any “back door” entry. This selection even prevents the drive manufacturer from being able to bypass the security of that drive.

A security level shall be available that prevents the drive from being flashed with new firmware.

* + - * 1. A checksum feature shall be used to notify the owner of unauthorized parameter changes made to the drive. The checksum feature includes two unique values assigned to a specific programming configuration.

One checksum value shall represent all user editable parameters in the drive except communication setup parameters. A second checksum value shall represent all user editable parameters except communication setup, energy, and motor data parameters.

Once the drive has been commissioned the two values can be independently saved in the drive.

The drive shall be configurable to either: Log an Event, provide a Warning, or Fault upon a parameter change when the current checksum value does not equal the saved checksum value.

* + - * 1. The “Hand” and “Off” control panel buttons shall have the option to be individually disabled (via parameter) for drives mounted in public areas.
				2. The capability to disable Bluetooth on control panels that include Bluetooth functionality shall be provided.
			1. Network Communications
				1. The drive shall have an EIA-485 port with removable terminal blocks. The onboard protocols shall be BACnet MS/TP, Modbus, and Johnson Controls N2. Optional communication cards for BACnet/IP, LonWorks, Profibus, Profinet, EtherNet/IP, Modbus TCP, and DeviceNet shall be available. The use of third party gateways are not acceptable.
				2. The drive shall have the ability to communicate via two protocols at the same time, one onboard protocol and one option card based protocol. Once installed, the drive shall automatically recognize any optional communication cards without the need for additional programming.
				3. The drive shall not require a power cycle after communication parameters have been updated.
				4. The embedded BACnet connection shall be a MS/TP interface. The drive shall be BTL Listed to Revision 14 or later. Use of non-BTL Listed drives are not acceptable.
				5. The drive shall be classified as an Applications Specific Controller (B-ASC). The interface shall support all BIBBs defined by the BACnet standard profile for a B-ASC including, but not limited to:

Data Sharing: Read Property Multiple-B, Write Property Multiple-B, COV-B

Device Management: Time Synchronization-B

Object Type Support: MSV, Loop

* + - * 1. The drive’s relay output status, digital input status, analog input/output values, Hand-Auto status, warning and fault information shall be capable of being monitored over the network. The drive’s start/stop command, speed reference command, relay outputs and analog outputs shall be capable of being controlled over the network. Remote drive fault reset shall be possible.
			1. Disconnect – A circuit breaker or disconnect switch shall be provided when indicated on the drive schedule. The disconnect shall be door interlocked and padlockable. Drive input fusing shall be included on all packaged units that include a disconnecting means. All disconnect configurations shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label. Disconnect packages manufactured by anyone other than the drive manufacturer, are not acceptable.
			2. Bypass – Bypass drive packages shall be provided when indicated on the drive schedule. All drive/bypass configurations shall be UL Listed by the drive manufacturer as a complete assembly and carry a UL508 label. Bypasses manufactured by anyone other than the drive manufacturer, are not acceptable.
				1. The drive and bypass package shall be a complete factory wired and tested bypass system consisting of a padlockable disconnect device, drive output contactor, bypass contactor, and drive input fuses.
				2. The drive and bypass package shall have a UL listed short circuit current rating of 100 kA, for 240 VAC and 480 VAC systems, and this rating shall be indicated on the rating label.
				3. The bypass control shall be powered by a three-phase switch mode power supply with a voltage tolerance of +30%, -35%. Single-phase power supplies and control power transformers (CPT) are not acceptable.
				4. The drive and bypass package shall be seismic certified and labeled to the IBC. Seismic importance factor of 1.5 rating is required, and shall be based upon actual shake table test data as defined by ICC AC-156. Seismic certification of equipment and components shall be provided by OSHPD preapproval.
				5. All bypass packages shall utilize a dedicated LCD bypass control panel (keypad) user interface. The bypass control panel must be a separate display from the drive control panel. Bypass packages that use a single shared drive/bypass control panel are not acceptable, due to that control panel acting as a single point of failure.

The bypass shall include a two-line, 20-character LCD display. The display shall allow the user to access parameters and view:

Bypass input voltage, current (Amps) and power (kW)

Bypass faults, warnings, and fault logs

Bypass operating time and energy consumption (resettable)

The bypass control panel shall include the following controls:

Four navigation keys (Up, Down, Enter, Escape)

Bypass Hand-Off-Auto, Drive mode / Bypass mode selectors, Bypass fault reset

The following indicating lights (LED PTT type) or control panel display indications shall be provided.

Drive mode selected, Bypass mode selected

Drive running, Bypass running

Drive fault, Bypass fault

Safety interlock and run permissive status shall be displayed using predetermined application specific nomenclature, such as: Damper end switch, smoke alarm, vibration trip, and overpressure.

* + - * 1. All bypasses shall have the following hardware features/characteristics as standard:

Six (6) digital inputs and five (5) Form-C relay outputs. The digital inputs shall be capable of accepting both 24 VDC and 24 VAC. The bypass control board shall include an auxiliary power supply rated 24 VDC, 250 mA.

Drive isolation fuses shall be provided. Bypass designs which have no such fuses, or that only incorporate fuses common to both the drive and the bypass are not acceptable. Third contactor “isolation contactors” and service switches are not an acceptable alternative to drive isolation fuses.

The bypass shall be able to detect a single-phase input power condition while running in bypass, disengage the motor, and provide a single-phase input power indication.

The bypass shall be designed for stand-alone operation and be completely functional in both Hand and Automatic modes, even if the drive and/or drive’s control board has failed. Network communications shall remain functional. Bypass systems that do not maintain full functionality in the event of a drive failure, are not acceptable.

* + - * 1. All bypasses shall have the following software features as standard:

Programmable loss-of-load (broken belt / coupling) indication shall be functional in drive and bypass mode.

The bypass shall also support run permissive and start interlock control functionality, including start delay, as previously specified in the drive section.

The bypass control shall monitor the status of the drive and bypass contactors and indicate when there is a welded contactor contact or open contactor coil.

The bypass shall include a selection for either manual or automatic transfer to bypass. The automatic transfer mode shall allow the user to select the specific drive fault types that result in an automatic transfer to bypass. The automatic transfer mode shall not allow a transfer to bypass on motor related faults. Automatic transfer schemes that do not differentiate between fault types, are not acceptable.

The bypass shall include the ability to select the operating mode of the system (Drive/Bypass) from either the bypass control panel or digital input.

The bypass shall include a supervisory control mode that monitors the value of the drive’s analog input (feedback). This feedback value is used to control the bypass contactor on/off state. The supervisory mode shall allow the user to maintain hysteresis control over applications such as cooling towers and booster pumps.

Selectable Class 10, 20, or 30 electronic motor overload protection shall be included in both drive and bypass mode.

The drive and bypass shall be designed to operate as an integrated system when in Override mode. Whether operating in drive or bypass mode, the low priority safeties will be ignored, and high priority safeties will be followed. External start/stop commands will be ignored. There shall be four selectable Override modes:

Bypass only, with two smoke control modes:

Fixed pre-configuration of digital inputs

Configurable high/low priority safeties and faults, to allow configuration to meet needs of local Authority Having Jurisdiction.

Drive only

Drive then transfer to bypass, in the event of a drive fault

Force to Stop

* + - * 1. Network communications – the bypass shall include BACnet MS/TP, Modbus, and Johnson Controls N2 as standard. The bypass BACnet implementation shall be BTL Listed to Revision 14 or later. Optional communication cards for BACnet/IP, LonWorks, Profibus, Profinet, Ethernet/IP, Modbus TCP, and DeviceNet shall be available.

The bypass relay output status, digital input status, warning and fault information can be monitored over the network. Status information shall be monitored, including; operating mode (drive vs bypass), current drawn in bypass mode, broken belt, and phase-to-phase voltage. The bypass start/stop command, force to bypass command, and relay outputs shall be capable of being controlled over the network.

* 1. EXECUTION
		1. INSTALLATION
			1. The responsible party shall install the drive in accordance with the recommendations of the drive manufacturer as outlined in the drive installation manual.
			2. Power wiring shall be completed by the responsible party. All wiring shall be installed in accordance with the recommendations of the drive manufacturer as outlined in the installation manual.
			3. Installation shall be in accordance with national, state and local building and electrical codes as may be in force in the installation area.
		2. START-UP
			1. Start-up shall be provided for each drive by an authorized local service provider.
		3. PRODUCT SUPPORT
			1. Factory trained application engineering and service personnel that are thoroughly familiar with the drive products offered shall be locally available at both the specifying and installation locations. A toll free 24/365 technical support line connected to factory support personnel located in the US and Canada shall be available.
			2. Training shall include installation, programming and operation of the drive, bypass and network communications. Owner training shall be provided locally upon request.
		4. WARRANTY
			1. The drive Product Warranty shall be 30 months from the date of shipment from the factory. The warranty shall include: Parts, on-site labor, and travel time and travel costs, or replacement of the complete drive as determined by the drive manufacturer’s technical support.

End of Section

1. SECTION 23 09 80 BMS – Energy Dashboard
	1. GENERAL
		1. Related Sections
			1. SECTION 23 09 13, BMS Instrumentation and Control Devices
			2. ECTION 23 09 33, Variable Frequency Drives
			3. SECTION 23 09 80, Energy Dashboard
			4. DIVISION 26 - Wiring Devices
		2. General Description
			1. The BMS Energy Dashboard shall be a cloud-based energy management system that gathers the information from energy meters in real-time and provides access to the energy and sensor information via a secure login to facilitate the management of energy, sustainability and building energy performance targets.
			2. The Energy Dashboard shall be scalable to provide an enterprise view of either a single facility or a portfolio of building assets as defined by the needs of the Owner.
			3. The Energy Dashboard shall meet internationally recognized energy management standards EN16001 and ISO50001.
		3. Work Included
			1. The BMS Contractor shall provide the Energy Dashboard application including but not limited to the connectivity infrastructure, data network (BMS LAN), integration of building system data relative to energy including but not limited to Building Management System (BMS), Metering Control System (MCS), and the Integrated Lighting Control System (ILCS).
			2. Integrate data from the following systems and devices into the Energy Dashboard application:
				1. Building Management System (BMS)
				2. Electricity meters
				3. Water meters
				4. Gas meters
				5. Utility meters
				6. Virtual meters (HVAC and Lighting Loads)
				7. Electrical panel boards if specified with smart meters
				8. Integrated Lighting Control System (ILCS)
			3. The BMS Contractor is responsible to integrate the data from building systems and configure the Energy Dashboard as defined by the owner and the information provided herein.
			4. Coordinate Internet connections and web access with the Owner.
	2. PRODUCTS
		1. Acceptable Products
			1. ABB AbilityTM Active Energy
		2. Energy Dashboard
			1. Security
				1. Provide a cloud-hosted Energy Dashboard with the following security features:

When the application is accessed using a browser, Secure Socket Layer (SSL) technology shall be utilised to protect customers’ information using both server authentication and data encryption, ensuring data is safe, secure and available only to authorised personel with valid log-in details.

To ensure reliability, data is to be duplicated across multiple disks, machines and data centres availability zones. Data is to be backed up on a regular basis allowing restoration from backup in the event of a complete system failure

Servers shoud be monitored and alerts raised if problems are detected.

The servers are to be hosted in a secure server environment that uses a firewall and other advanced technology to prevent interference or access from outside intruders.

Data travelling between the customers’ site and the Data Storage Servers should be encrypted using HTTPS protocol (encrypted HTTP), so that it cannot be intercepted.

Users access to the system is to be on a ‘least privilege‘ basis with each user only being granted access to what they require to carry out their role. This is achieved by granting users access to roles which are defined on a granular basis – i.e. Role Based Access Control.

* + - 1. Data Collection
				1. The Energy Dashboard shall be a flexible energy management platform that can collect data from many data sources including Building Management System (BMS) and enterprise level systems such as SQL databases where information relating to the energy consumption in a building is held.
				2. Data is to be collected direct from the meters, typically in intervals of 15 minutes and collection is to be monitored remotely. Provide the capability to upload historical data manually to the system to enable trend analysis.
			2. Analytics
				1. The Energy Dashboard application shall provide the following features:

Energy Targeting and Analysis

Multiple regression analysis using energy drivers such as local weather, building occupancy or production levels to determine expected energy consumption within a building or part of a building. This can then be compared with actual energy consumption to determine if the building is performing efficiently.

Energy comparison – compare energy consumption between meters or between different time periods.

Standard pre-configured overspend dashboards / league tables comparing actual consumption to budget and expected consumption, to determine deviation from expected consumption and identify areas for improvement;

Scatter plots, overspend, cusum energy charts. Cusum analysis can be used to measure the savings achieved from an energy improvement measure and can be used in IPMVP reporting.

Rolling 12-month cumulative energy trends that can be used to illustrate a long-term energy glide path.

Spectral analysis (heat map) charts that show the energy profile of a meter by applying a colour profile over a day, week, month or annual period. Useful for identifying energy consumption outside of core hours.

Degree day analysis – Heating Degree Days (HDD) and Cooling Degree Days (CDD). HDD and CDD to be calculated at any datum point using local building weather data or local weather station data.

Benchmarking/Normalization – allowing the energy performance of different buildings to be compared and benchmarked. Normalization allows fair comparison between buildings of different sizes using metric such as KWh/m2(ft2)/per annum or Co2/m2(ft2)/per annum. Helps identify best performing areas or buildings to enable best practice to be implemented in poorer performing areas.

Unit Conversions – Allow data to be displayed in preferred engineering units. For example, convert gas consumption data to KWh from m3. Unit conversions to be time bound, so if the calorific value of the gas changes, the system can be updated to reflect this.

Cost or Emissions conversion – Allows the user to convert to see associated costs or CO2 emission levels. Conversions to be time bound, so if energy price or CO2 conversion rate changes, the system can be updated to reflect this.

Primary Energy Reporting – Allows the user to convert to see primary energy consumption.

Virtual meters

There should be the ability to display any number of virtual meter calculations on the EMT system as required by the customer. In additional there should be the ability to manually upload manual meter readings to the system to augment existing monitored meters, where it is not possible to automate the data collection from a meter.

Alarms

Alarms to be viewed via the map-based interface.

Configuration of two types of alarms:

Email alarm notification for deviation from expected consumption, along with alarm history tracking and the ability to set multiple alarms per meter point.

Email alarm notification based on a fixed level – for example, alert if consumption exceeds a preset level today or if energy consumption exceeds a preset level in any 15 minute.

League Tables

The following League Tables are to be provided:

Energy usage versus target energy use

Energy usage versus budget energy use

Performance deficit

Energy usage comparison

Emissions

Cost comparison

Meter Attributes

Attributes can be associated with each meter, in order to allow the user to ﬁlter and analyse energy usage meter data on any attribute or characteristic.

Meter data can be analysed and ﬁltered across multiple attributes.

Customized Reporting

Ability to generate instant or scheduled reports on energy consumption, costs, carbon emissions, performance versus expected energy usage, as well as CUSUM and 12 month Rolling views. Customised reports are to be saved in pdf format to share with key stakeholders. It should also be possible to edit customised reports to, for example, to add comments prior to sharing the report.

Configurable Scheduled Reports should be set to run at regular intervals – e.g. daily, weekly or monthly.

CSV Reporting

Ability to provide a CSV export feature for meter attributes. CSV Report types shall include:

Out of Hours Use Reports

Energy consumed during times of year – for example, in an education establishment, to show the energy consumed during term time.

Energy consumed over specificed times – for example, in an education establishment, to show the energy consumed during evenings or weekends, when part of the building may be used by third parties.

Energy Recharging Reports

Multiple tariﬀ structures can be added and applied to a meter as an attribute, to generate energy recharge reports automatically. Apportionment, where there are several users of a space and the energy costs need to be split.

Ability to include the actual meter reads at the start and end of the billing period, so the recharging reports are transparent and can easily be verified by the tenant.

Ability to recharge energy costs ahead of the main utility bill. Tenants can receive bills reﬂective of their actual usage rather than averages or estimates based on square footage.

Utility Bill Verification

Ability to generate energy bills, based on time of use – (summer/winter, day/night, weekday/weekend etc), as well as ﬁxed charges such as MIC (maximum import capacity) and standing charges, for direct comparison against energy provider bills.

Public Energy Display

Provide a web-based public information display that communicates information on a building’s energy performance and provides tips and recommendations of how building users can assist in reducing energy consumption.

Owner shall supply the new smart display(s) to the BMS Contractor. BMS Contractor shall be responsible for the installation and connectivity of the displays. Coordinate with the Owner.

Location of public information display(s):

XXX

* + 1. EXECUTION
			1. Installation
				1. The Energy Dashboard shall be installed by a factory-authorized service representative.
				2. Review and reference this complete Specifications and Drawings for each integration and identify any gaps or potential conflicts in technology architecture or scope of work. Communicate the discrepancies via the RFI process at least five working days prior to the bid.

End of Section

1. SECTION 23 09 93 BMS Sequences of Operations
	1. GENERAL
		1. Sequences of Operation

End of Section