

PART 1 - GENERAL

1.01 SECTION INCLUDES

- A. System Description.
- B. Operator Interface.
- C. Controllers.
- D. Electrical Control Power Wiring and Low Voltage Wiring.
- E. Local Area Network.
- F. System Software.
- G. Controller Software.

1.02 REFERENCE STANDARDS

- A. ANSI/CEA 709.1.D - Control Network Protocol Specification; 2014.
- B. ASHRAE Std 135 - BACnet - A Data Communication Protocol for Building Automation and Control Networks; most current edition.
- C. IEEE C37.90.1 – IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus, most current edition.
- D. IEEE C62.41.2 – IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and less) AC Power Circuits, most current edition.
- E. ISO 7498 – Information Processing Systems – Open System Interconnection – Basis Reference Model, International Standards Organization, most current edition.
- F. NEMA – National Electrical Manufacturers Association.
- G. NFPA 70 - National Electrical Code; National Fire Protection Association; Most Recent Edition Adopted by Authority Having Jurisdiction, Including All Applicable Amendments and Supplements.

1.03 ADMINISTRATIVE REQUIREMENTS

- A. Preinstallation Meeting: Conduct a preinstallation meeting one week prior to the start of the work of this section; require attendance by all affected installers.

1.04 DEFINITIONS

- A. ASC: Application Specific Controller. Examples include controllers for specific applications (e.g., FCU, VAV box, etc.) that can be configured through any network services software.
- A. ATU: Air Terminal Unit (e.g., VAV boxes, fan-powered boxes, fan coil units).
- B. BAS: Building Automation System.
- C. BTL: BACnet Testing Laboratories. Third party independent testing and listing program for devices which have been tested according to ASHRAE Standard 135.
- D. Control Wiring: Includes conduit, wire and wiring devices to install complete control systems including motor control circuits, interlocks, thermostats, EP and IP switches and like devices. Includes all wiring from Intelligent Devices and Controllers to all sensors and points defined in the input/output summary shown on the drawings or specified herein and required to execute the sequence of operations
- E. DDC: Direct Digital Control.
- F. EMT: Electrical Metallic Tubing
- G. High voltage: 50 volts or higher.
- H. IP: Internet Protocol.
- I. LAN: Local Area Network.
- J. VLAN: Virtual Local Area Network.
- K. Low voltage: Below 50 volts.
- A. NiCS: Niagara Compatibility Statement license.
- L. OSI: Open System Interconnection
- M. PC: Personal Computer.
- N. PICS: Protocol Implementation Conformance Statement.
- O. Point: Point is a generic term used to describe a single item of information in a BAS. Points may be further described as input, output, digital, binary, discrete, analog, modulating, internal, external, virtual or global. Each unique point used by digital controllers, or in a BAS, is typically identified by an address.

1.05 CONTRACTOR RESPONSIBILITIES

- A. Reference the following sections for additional contractor responsibilities and coordination:
 - 1. Division 23 Section “Electrical Coordination for Mechanical Equipment.”
 - 2. Division 23 Section “Commissioning for HVAC.”
 - 3. Division 23 Section “Instrumentation and Control Devices for HVAC.”
- B. Reference Part 3 for additional electrical contractor responsibilities for BAS controls.

1.06 SUBMITTALS

- A. Refer to Division 01 and Division 23 Section “General Mechanical Requirements” for submittal procedures.
- B. General:
 - 1. The drawings and specifications are not intended to show all details. The BAS contractor shall secure satisfactory information before submitting the proposal and include in the proposal a sum sufficient to cover all items of labor and material required for the complete installation for the devices and system described.
 - 1. Inform Engineer in writing of any deviation in the exhibits submitted from the requirements of the drawings, specifications, and sequences of operations.
- C. Product Data:
 - 1. Submit manufacturer technical data for each system component and software module required for a complete installation.
 - 2. Indicate dimensions, weights, and enclosure construction for all BAS distributed controllers.
 - 2. Submit technical data on all new software supplied including description of functions performed by software and location within the system where software shall reside. Include all software licensing agreements.
 - 3. Submit the PICS for each BACnet device used in the BAS.
 - 4. Submit the NiCS for each type of Niagara station in the BAS.
- D. Power and Communication Wiring Transient Protection:
 - 1. Submit catalog data sheets providing evidence that all BAS products offered by the manufacturer are tested and comply with IEEE C62.41.2.
 - 2. Testing shall include power and communication trunk wiring.
 - 3. Compliance with IEEE C62.41.2 shall imply conformance with IEEE C37.90.1 based on the stated position of ANSI and IEEE.
- E. Shop Drawings:

1. Submit a trunk cable schematic showing locations of all programmable control units, controllers, and workstations, with associated network wiring.
 - a) Indicate equipment served by each controller on the diagram.
 - b) Indicate switches, power requirements to each controller, and daisy chained controllers.

3. Submit detailed schematic control drawings for each controlled device and equipment.
 - c) Reference all control components to manufacturer make and model number.
 - d) Include all control and power wiring with termination point (controller and terminal number).
 - e) Include clearly indicated and written sequences of operation referenced to specific control components (e.g., "shall modulate valve V-3").
 - f) Include default position (e.g., N.O., N.C., etc.) for all components where applicable.
 - g) Clearly differentiate between existing components and new components.
 - a. Include detailed wiring diagrams showing methods of connections to VFDs, motor starters, energy meters, and all other devices, and all other field wiring necessary for system installation.
 - b. The use of "typicals" will be allowed where appropriate.

2. Submit detailed drawings for each individual BAS distributed controller.
 - a) Include controller identification.
 - b) Include components included in the controller.
 - c) Include numbering of terminals and communications ports.
 - d) List connected data points, including connected control unit and input device.
 - e) Include type of cable connected to each terminal port.
 - f) Identify specific field devices wired to each terminal including identification of each field device and application.
 - g) Clearly differentiate between existing controllers and new controllers.
 - h) Indicate source (electrical panel ID) of 120V power to each panel to which 120V power is connected.
 - i) Indicate method of connecting controller to equipment supplied by others and to existing communications networks.
 - j) Indicate device instance and network number.

3. Submit floor plans that indicate the following:
 - a) Location of all new BAS distributed controllers and control panels.
 - b) Routing of all new building level network communications wiring not located in mechanical and electrical rooms.
 - c) Routing of wiring to controllers, sensors, and control points not located in mechanical and electrical rooms.

- d) Location of building system connection to Owner's campus wide data network.
 - 4. Submit methods and materials used to integrate into existing networks.
 - 5. All control drawings and schematics shall be generated using AutoCAD software or equivalent. All project drawings shall be supplied to the Owner in a format as desired by the Owner upon project completion.
 - 4. Submit system identification nomenclature.
 - a) Nomenclature shall be consistent throughout the network and consistent with any existing networks that are integrated. If not defined, nomenclature shall be similar to the point names shown on the drawings.
 - b) Object name and ID number shall be unique within a control device.
 - c) Control device instance name and ID number shall be unique within the network.
 - d) Network number shall be unique for each unique electrical segment in the BAS.
 - 6. Indicate system graphics indicating monitored systems, data (connected and calculated) and operator notations.
 - a) Submit example graphic visualizations and screenshots for the BAS. At a minimum, submit examples for major HVAC equipment components, including chillers, boilers, air handling units, fan coil units, heat pumps, fans, etc.
 - b) Font size and type shall be manufacturer standard.
 - c) Provide graphics demonstration package in a format as desired by the Owner.
 - 7. Indicate description and sequence of operation of operating, user, and application software.
- F. System Analytics Database: Submit a database interface plan to Owner.
- 1. Plan shall demonstrate the look of the BAS interface.
 - 2. Include example graphics of proposed trending functionality and archive functionality.
 - 3. Plan shall be approved by Owner to meet their intent for accessibility and user-friendliness.
- G. Manufacturer's Instructions: Indicate manufacturer's installation instructions for all manufactured components.
- H. Manufacturer's qualification statement.
- I. Installer's qualification statement.
- J. Project Record Documents: Record actual locations of control components, including control units, thermostats, and sensors.

1. Revise shop drawings to reflect actual installation and operating sequences.
 2. Include submittals data in final "Record Documents" form.
 3. All additions or changes to the BAS during the course of construction shall be reflected upon the drawings and submitted to the Engineer before project close-out.
- K. Testing and Commissioning Reports and Checklists: Submit completed versions of all reports and checklists, along with all trend logs, used to meet the requirements of Part 3, Startup and Demonstration.
- L. Operation and Maintenance Data:
1. Include maintenance data and recommended spare parts list for digital control equipment and control components.
 2. Include trouble-shooting maintenance guides.
 3. Include interconnection wiring diagrams showing complete field installed systems with identified and numbered system components and devices.
 4. Include keyboard illustrations and step-by-step procedures indexed for each operator function.
 5. Include inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
 6. Include a maintenance manual which contains the information listed above, product data, shop drawings, final software code for sequences of operation and maintenance data in accordance with requirements of Division 01.
 7. Include logbook for documentation of software updates and patches applied BAS for the time period included in the software licensing agreement.
 8. Provide names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
- M. Warranty: Submit manufacturer's warranty and ensure forms have been filled out in Owner's name and registered with manufacturer.
- N. Maintenance Materials:
1. Refer to Division 01 for additional provisions.
 2. Extra Stock Materials: Two printer cartridges and cartons of printer paper.

1.07 QUALITY ASSURANCE

- A. Perform work in accordance with NFPA 70.
- B. Products Requiring Electrical Connection: Listed and classified by Underwriters Laboratories Inc., as suitable for the purpose specified and indicated.
- C. BACnet devices used in the BAS shall be BTL listed according to its device profile.
- D. Manufacturer Qualifications: Company specializing in manufacturing the Products specified in this section with minimum three years documented experience.

- E. Installer Qualifications: Company specializing in performing the work of the type specified and with minimum documented experience as follows:
 - 1. All personnel of the BAS Contractor shall have a minimum of three years of experience within their appropriate trades.
 - 2. All subcontractors utilized by the BAS Contractor shall have a minimum of five years experience within their appropriate trades.

- F. Additional BAS Contractor Requirements:
 - 1. Personnel, Coverage and Response Capabilities: The BAS Contractor shall have a fully staffed office with service technicians and systems engineers within a 50 mile radius of the project location.
 - 2. Parts Stocking: The BAS Contractor shall have an independently verifiable inventory of electronic service parts. This electronic service parts inventory must have a worth of at least \$100,000 per year over the last five years.
 - 3. Past Projects: The BAS Contractor shall have completed a minimum of twenty projects within the last five years which are at least equal in dollar value and comparable scope to this project. A list of similar projects, dollar volume, scope, contact name and contact number shall be provided by the BAS Contractor if asked for by the Owner.

1.08 WARRANTY

- A. Refer to Division 01 for additional project warranty requirements.

- B. Labor and materials for the BAS specified shall be warranted free from defects in workmanship and material for a period of 2 years after Substantial Completion and system acceptance.

- C. BAS failures during the warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to the Owner.

- D. All work shall have a single warranty date, even when the Owner has received beneficial use due to an early system start-up. If the work specified is split into multiple contracts or a multi-phase contract, then each contract or phase shall have a separate warranty start data and period.

- E. Provide updates to operator workstation software, project-specific software, graphic software, database software, and firmware that resolve Contractor-identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.

- F. Provide five year manufacturer's warranty for field programmable micro-processor based units.

- G. Special warranty on instrumentation:

1. All instrumentation shall be covered by manufacturer's transferable one-year "No Fault" warranty. If manufacturer warranty is not available, the BAS installer shall provide the same.

1.09 PROTECTION OF SOFTWARE RIGHTS

- A. Prior to delivery of software, the Owner and the party providing the software will enter into a software license agreement with provisions for the following:
 1. Limiting use of software to equipment provided under these specifications.
 2. Limiting copying.
 3. Preserving confidentiality.
 4. Prohibiting transfer to a third party.
- B. Software provider shall provide software updates and patches to the BAS as part of the software licensing agreement as the updates and patches are released. If any security vulnerabilities are discovered by the provider, the provider shall notify the client within five business days.
- C. Ownership of Proprietary Material: Project-specific software and documentation shall become Owner's property upon project completion. This includes, but is not limited to the following:
 1. Graphics.
 2. Record drawings.
 3. Database.
 4. Application programming code.
 5. Documentation.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

- A. Corporate Edition Products: The following manufacturers and product lines shall be manufacturer's most current vintage and of open protocol design. Corporate editions shall be based on manufacturer developed software.
 1. Automated Logic, WebCtrl.
 2. Delta Controls, enteliBUS.
 3. Johnson Controls, Metasys.
 4. Schneider Electric, EcoStruxure Building Operation.
- B. The above list of manufacturers applies to operator workstation software, controller software, the custom application programming language, building controllers, custom application controllers, and application specific controllers. All other products specified under Division 23 Section "Instrumentation and Control Devices for HVAC" need not be manufactured by the above manufacturers.

2.02 SYSTEM DESCRIPTION

A. General:

1. The BAS shall consist of all necessary hardware and software to perform the control sequences of operation as called for in the Specifications and Drawings. Contractor shall install and commission all necessary devices to ensure a reliable and stable network.
2. System design is based on a distributed system of fully intelligent, stand-alone controllers, operating in a multi-tasking, multi-user environment on token passing network, with central and remote hardware, software, and interconnecting wire and conduit.
3. Include computer software and hardware, operator input/output devices, control units, local area networks (LAN), sensors, control devices, actuators.
4. The BAS shall be capable of integrating multiple devices, sensors, and functions from multiple control vendors into a common front end, including equipment supervision and control, alarm management, energy management, and trend data collection.
5. The BAS shall be modular in nature, and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, ASC's, and operator devices.
6. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

B. Local Area Network:

1. The BAS shall be set up as a physically separate network within the building.

C. Network Architecture: The BAS network architecture shall be based upon the OSI basic reference model in accordance with ISO 7498.

1. Application/Network Layer:
 - a) BACnet protocol complying with ASHRAE Standard 135.
2. Physical/Data Link Layer:
 - a) Hard-wired type:
 - 1) Ethernet according to ISO 8802-2 protocol.
 - 2) EIA-485 Twisted Cable Pair according to Master Slave/Token-Passing (MS/TP) protocol.
3. Communication between operator workstation(s) and building controller(s):
 - a) Ethernet.
4. Communication between building controller(s) and application specific and custom application controllers:

- a) MS/TP.
- b) PTP.

D. Web Services Enabled Network:

- 1. The network shall be capable of being accessed remotely over the internet via a virtual link according to Internet Protocol.
- 2. System software shall be based on a client/server architecture, designed around the open standards of web technology. The BAS server shall be accessed using a web browser over the BAS network, Owner's LAN, and remotely over the Internet (through the Owner's LAN).
- 3. No special software other than a web browser shall be required to access graphics, point displays, and trends, configure trends, configure points and controllers, or to edit programming. Connection shall be browser agnostic.

E. Network Integration:

- 1. The BAS network shall be integrated with other automation networks controlled by the Owner. Coordinate with the Owner's information technology (IT) department for networks that shall be integrated.
- 2. Provide gateways or other integration devices across networks with different communication protocol to provide a single network visibility and interoperability at the operator workstation. Coordinate communication protocol with each automation system specified.
- 3. Interoperable networks shall be capable of sharing all point and point information across networks to a single BAS front end.
- 4. Interoperable networks shall be capable of automatically downloading application program changes.
- 5. For integrated networks that cannot automatically download application program changes, provide a link to the Controller Manual Download Schedule, as defined in the submittals section of Part 1 on the BAS front end summary page
- 6. Integrate the following networks:
 - a) Boiler plant master firing controller.
 - b) Chiller controller.
 - c) Lighting control systems.
 - d) Security systems.
 - e) Life safety systems.
 - f) Fire alarm control panels.
 - g) Security managers.
 - h) Vehicle emission controller.

F. Network Interoperability:

- 1. Provide communication between control units over local area network (LAN).
- 2. Communication services over the LAN shall result in operator interface and value passing that is transparent to the network architecture as follows:

- a) Connection of an operator interface device to any one controller on the network shall allow the operator to interface with all other controllers as if that interface were directly connected to the other controllers. Data, status information, reports, system software, custom programs, etc., for all controllers shall be available for viewing and editing from any one controller on the network.
- b) All database values (e.g., objects, software variables, custom program variables) of any one controller shall be readable by any other controller on the network. This value passing shall be automatically performed by a controller when a reference to an object name not located in that controller is entered into the controller's database. An operator/installer shall not be required to set up any communication services to perform network value passing.

2.03 OPERATOR INTERFACE

A. General:

- 1. The Operator Interface shall provide overall BAS supervision and system software interface. Communications from the workstation shall be executed directly to and between the integration level building controllers and field level controllers.
- 2. The operator interface shall be capable of command entry, information and alarm management, database management, access of all system data, and be independent of hardware technology.

B. Hardware:

1. Desktop:

- a) Computer(s) and display(s) to be provided by BAS controls manufacturer.
- b) PC shall be general purpose and commercially available, with sufficient memory and processing capability to meet the requirements of the BAS.
 - 1) Quantity: 1.
- 1) Minimum RAM: 4.0 gigabytes.
 - 2) Minimum Processing Speed: Intel i3 Dual Core Microprocessor or better running at no less than 3.0 gigahertz.
 - 3) Minimum Hard Drive Memory: 500 gigabytes.
- 2) Drives: 32X CD Rom/8X DVD drive.
 - 4) Ports:
 - a) Minimum of 2 USB 2.0 or faster ports on front of tower.
 - b) Minimum of 2 free USB 2.0 or faster ports on rear of tower.

- b. Monitor: Minimum 17 inch VGA or higher resolution, color graphic LCD or LED monitor with a compatible VGA or higher resolution card.
 - c) Location(s): As directed by the Owner.
 - d) Network Connection:
 - 1) Suitable for network technology provided.
 - 2) Ethernet interface card with minimum Speed: 10/100/1000.
 - e) Standard 101 key keyboard.
 - f) Standard mouse with track wheel.
- 2. System Printer:
 - a) Printer(s) to be provided by BAS controls manufacturer.
 - b) Quantity: 1.
 - c) Type: Business/office quality inkjet or laser jet equivalent printer.
 - d) Resolution: Up to 600 x 1200 dots per inch (dpi) black and up to 4800 x 1200 dpi color.
 - e) Minimum Print Speed: Minimum 18 ppm black and 10 ppm color.
 - f) Locations(s): As directed by the Owner.
- 3. Database Save/Restore/Back-Up:
 - a) Back-up copies of all Building Controller and ASC data as well as mass storage for trend logs shall be stored in the mass storage device designated by the Owner.

1.2 CONTROLLERS

C. Building Controllers

1. General:

- a) Input Power Requirements: 24Vac.
- b) Manage global strategies by one or more, independent, standalone, microprocessor based controllers.
- c) Provide sufficient memory to support controller's operating system, database, and programming requirements.
- d) Share data between networked controllers.
- e) Controller operating system manages input and output communication signals allowing distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
- f) Utilize real-time clock for scheduling.
- g) Continuously check processor status and memory circuits for abnormal operation.
- h) Monitor and assume predetermined failure mode and generate alarm notification upon detection of abnormal operation.
- i) Communication with other network devices to be based on assigned protocol.

- j) Monitor the status of all overrides, and include this information in logs and summaries to inform the operator that automatic control has been inhibited.

2. Communication:

- a) Perform routing when connected to a network of custom application and application specific controllers.
- b) Provide service communication port for connection to a portable operator's terminal or hand held device with compatible protocol.
 - 1) Port shall be USB type.

3. Anticipated Environmental Ambient Conditions:

- a) Outdoors and/or in Wet Ambient Conditions:
 - 1) Mount within NEMA 4X waterproof enclosures.
 - 2) Rated for operation at 40 to 150 degrees F and 95 percent RH, non-condensing.
- b) Conditioned Space:
 - 1) Mount within NEMA 1 dustproof enclosures.
 - 2) Rated for operation at 32 to 120 degrees F.

4. Local Keypad and Display for each Controller:

- a) Use for interrogating and editing data.
- b) System security password prevents unauthorized use.
- c) If the manufacturer does not normally provide a keypad and display for the controller, provide software and interface cabling needed to use a portable operator terminal for the system.

5. Provisions for Serviceability:

- a) Diagnostic LEDs for power, communication, and processor.
- b) Make all wiring connections to field removable, modular terminal strips, or to a termination card connected by a ribbon cable.

6. Memory: In the event of a power loss, maintain all BIOS and programming information for a minimum of 72 hours.

7. Power and Noise Immunity:

- a) Maintain operation at 90 to 110 percent of nominal voltage rating.
- b) Perform orderly shutdown below 80 percent of nominal voltage.
- c) Upon restoration of normal power, the controller shall automatically resume full operation without manual intervention.
- d) Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W. at 3 feet.

8. Surge and Transient Protection:

- a) Isolation shall be provided at all network terminations, as well as all field point terminations, to suppress induced voltage transients consistent with IEEE Standard C62.41.2.
- b) Isolation levels shall be sufficiently high as to allow all signal wiring to be run in the same conduit as high voltage wiring where acceptable by electrical code.

D. Custom Application Controllers

1. General:

- a) Input Power Requirements: 24Vac.
- b) Provide sufficient memory to support controller's operating system, database, and programming requirements.
- c) Share data between networked, microprocessor based controllers.
- d) Controller operating system manages input and output communication signals allowing distributed controllers to share real and virtual object information and allowing for central monitoring and alarms.
- e) Utilize real-time clock for scheduling.
- f) Continuously check processor status and memory circuits for abnormal operation.
- g) Monitor and assume predetermined failure mode and generate alarm notification upon detection of abnormal operation.
- h) Communication with other network devices to be based on assigned protocol.
- i) Monitor the status of all overrides, and include this information in logs and summaries to inform the operator that automatic control has been inhibited.

2. Communication:

- a) Provide service communication port for connection to a portable operator's terminal or hand held device with compatible protocol.

3. Anticipated Environmental Ambient Conditions:

- a) Outdoors and/or in Wet Ambient Conditions:
 - 1) Mount within NEMA 4X waterproof enclosures.
 - 2) Rated for operation at 40 to 150 degrees F and 95 percent RH, non-condensing.
- b) Conditioned Space:
 - 1) Mount within NEMA 1 dustproof enclosures.
 - 2) Rated for operation at 32 to 120 degrees F.

4. Provisions for Serviceability:

- a) Diagnostic LEDs for power, communication, and processor.
- b) Make all wiring connections to field removable, modular terminal strips, or to a termination card connected by a ribbon cable.

5. Memory: In the event of a power loss, maintain all BIOS and programming information for a minimum of 72 hours.
6. Power and Noise Immunity:
 - a) Maintain operation at 90 to 110 percent of nominal voltage rating.
 - b) Perform orderly shutdown below 80 percent of nominal voltage.
 - c) Upon restoration of normal power, the Digital Panel shall automatically resume full operation without manual intervention.
 - d) Operation protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W. at 3 feet.
7. Surge and Transient Protection:
 - a) Isolation shall be provided at all network terminations, as well as all field point terminations, to suppress induced voltage transients consistent with IEEE Standard C62.41.2.
 - b) Isolation levels shall be sufficiently high as to allow all signal wiring to be run in the same conduit as high voltage wiring where acceptable by electrical code.

E. Application Specific Controllers

1. General:

- a) Input Power Requirements: 24Vac.
- b) Not fully user programmable, microprocessor based controllers dedicated to control specific equipment.
- c) Customized for operation within the confines of equipment served.
- d) Provide sufficient memory to support controller's operating system, database, and programming requirements.
- e) Communication with other network devices to be based on assigned protocol.
 - 1) Each ASC shall be capable of stand-alone operation and shall continue to provide control functions without being connected to the network.
- f) Monitor and assume predetermined failure mode and generate alarm notification upon detection of abnormal operation.

2. Communication:

- a) Provide service communication port for connection to a portable operator's terminal or hand held device with compatible protocol.

3. Anticipated Environmental Ambient Conditions:

- a) Outdoors and/or in Wet Ambient Conditions:
 - 1) Mount within NEMA 4X waterproof enclosures.
 - 2) Rated for operation at 40 to 150 degrees F.
- b) Conditioned Space:

- 1) Mount within NEMA 1 dustproof enclosures.
- 2) Rated for operation at 32 to 120 degrees F and 95 percent RH, non-condensing.

4. Provisions for Serviceability:

- a) Diagnostic LEDs for power, communication, and processor.
- b) Make all wiring connections to field removable, modular terminal strips, or to a termination card connected by a ribbon cable.

5. Memory. In the event of a power loss, maintain all BIOS and programming information for a minimum of 72 hours.

6. Power and Noise Immunity:

- a) Maintain operation at 90 to 110 percent of nominal voltage rating.
- b) Perform orderly shutdown below 80 percent of nominal voltage.
- c) Upon restoration of normal power, the controller shall automatically resume full operation without manual intervention.
- d) Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W. at 3 feet.

7. Surge and Transient Protection:

- a) Isolation shall be provided at all network terminations, as well as all field point terminations, to suppress induced voltage transients consistent with IEEE Standard C62.41.2.
- b) Isolation levels shall be sufficiently high as to allow all signal wiring to be run in the same conduit as high voltage wiring where acceptable by electrical code.

F. Input/Output Interface

1. Hardwired inputs and outputs shall tie into the BAS through building, custom application, or application specific controllers.

2. All Input/Output Points:

- a) Protect controller from damage resulting from any point short-circuiting or grounding and from voltage up to 24 volts of any duration.
- b) Provide universal type for building and custom application controllers where input or output is software designated as either binary or analog type with appropriate properties.
- c) Universal-type inputs or outputs configurable between binary and analog are acceptable.

3. Binary Inputs:

- a) Allow monitoring of On/Off signals from remote devices.
- b) Provide wetting current of 12 mA minimum, compatible with commonly available control devices and protected against the effects of contact bounce and noise.

- c) Sense dry contact closure with power provided only by the controller.
- 4. Pulse Accumulation Input Objects: Conform to all requirements of binary input objects and accept up to 10 pulses per second.
- 5. Analog Inputs:
 - a) Allow for monitoring of low voltage 0 to 10 Vdc, 4 to 20 mA current, or resistance signals (thermistor, RTD).
 - b) Compatible with and field configurable to commonly available sensing devices.
- 6. Binary Outputs:
 - a) Used for On/Off operation or a pulsed low-voltage signal for pulse width modulation control.
 - b) Outputs provided with three position (On/Off/Auto) override switches.
 - c) Status lights for building and custom application controllers to be selectable for normally open or normally closed operation.
- 7. Analog Outputs:
 - a) Monitoring signal provides a 0 to 10 Vdc or a 4 to 20 mA output signal for end device control.
 - b) Provide status lights and two position (AUTO/MANUAL) switch for building and custom application controllers with manually adjustable potentiometer for manual override on building and custom application controllers.
 - c) Drift to not exceed 0.4 percent of range per year.
- 8. Tri State Outputs:
 - a) Coordinate two binary outputs to control three point, floating type, electronic actuators without feedback.
 - b) Limit the use of three point, floating devices to the following zone and terminal unit control applications:
 - 1) VAV terminal units.
 - 2) Duct mounted heating coils.
 - 3) Zone dampers.
 - 4) Radiant devices.
 - c) Control algorithms shall run the zone actuator to one end of its stroke once every 24 hours for verification of operator tracking.

2.04 ELECTRICAL CONTROL POWER AND LOW VOLTAGE WIRING

- A. Power Wiring: Copper wiring, plenum cable, and raceways shall be as specified in the applicable section of Division 26.
- B. Power and Communication Wiring Transient Protection:

1. Comply with IEEE C62.41.2.
2. Communications trunk wiring shall be protected with a transient surge protection device providing the minimal protection required.
3. Communication circuitry, input/output circuitry, and communication unit shall provide protection against a 1000 volt, 3 amp transient signal, directly applied to the communication or input/output terminations.
 - a) For systems not complying with this requirement, provide equivalent protection external to the automatic temperature control system controller. Protection shall be provided for the individual communications and input/output terminations for each automatic temperature control system controller.
 - b) Submittal documentation shall clearly define how this requirement will be met and how the external protection will not affect the performance of the controllers.

C. Power Supplies:

1. Provide UL listed control transformers with Class 2 current limiting type or over-current protection in both primary and secondary circuits for Class 2 service as required by the NEC.
2. Limit connected loads to 80 percent of rated capacity.
3. Match DC power supply to current output and voltage requirements.
4. Supplies shall be full wave rectifier type with output ripple of 5.0 mV maximum peak to peak.
5. Regulation to be 1 percent combined line and load with 100 microsecond response time for 50 percent load changes.
6. Provide over-voltage and over-current protection to withstand a 150 percent current overload for 3 seconds minimum without trip-out or failure.
7. Operational Ambient Conditions: 32 to 120 degrees F.
8. EM/RF meets FCC Class B and VDE 0871 for Class B and MIL-STD 810 for shock and vibration.
9. Line voltage units UL recognized and CSA approved.

D. Power Line Filtering:

1. Provide external or internal transient voltage and surge suppression component for all workstations and controllers.
2. Minimum surge protection attributes:
 - a) Dielectric strength of 1000 volts minimum.
 - b) Response time of 10 nanoseconds or less.
 - c) Transverse mode noise attenuation of 65 dB or greater.
 - d) Common mode noise attenuation of 150 dB or greater at 40 to 100 Hz.

E. Input/Output Control Wiring

1. Control wiring shall be sized to accommodate the voltage drop associated with the distance between the control device and the controller. Minimum size shall be as specified herein.
 2. In all communication conduits, provide one spare twisted pair to be installed, tagged and labeled at each end.
 3. Control wiring not installed in conduit shall be UL rated for plenum installation.
 4. Ethernet control wiring shall be fiber optic or single pair of solid 24 gauge twisted, shielded copper cable.
 5. RTD wiring shall be three-wire or four-wire twisted, shielded, minimum number 22 gauge.
 6. Other analog inputs shall be a minimum of number 22 gauge, twisted, shielded.
 7. Binary control function wiring shall be a minimum of number 18 gauge.
 8. Analog output control functions shall be a minimum of number 22 gauge, twisted, shielded.
 9. Binary input wiring shall be a minimum of number 22 gauge, twisted, shielded.
 10. Thermistors shall be equipped with the manufacturer's calibrated lead wiring.
 11. 120V control wiring shall be #14 THHN in 3/4 inch conduit. Provide 20% fill extra wire in each conduit.
- F. Splices: Splices in shielded cables shall consist of terminations and the use of shielded cable couplers that maintain the integrity of the shielding.
- G. Conduit and Fittings
1. Conduit for Control Wiring, Control Cable and Transmission Cable: EMT with compression fittings, cold rolled steel, zinc coated or zinc-coated rigid steel with threaded connections.
 2. Outlet Boxes (Dry Location): Sheradized or galvanized drawn steel suited to each application, in general, four inches square or octagon with suitable raised cover.
 3. Outlet Boxes (Exposed to Weather): Threaded hub cast aluminum or iron boxes with gasket device plate.
 4. Pull and Junction Boxes: Size according to number, size, and position of entering raceway as required by National Electrical Codes. Enclosure type shall be suited to location.
- H. Relays
1. Relays other than those associated with digital output cards shall be general purpose, enclosed plug-in type with 8-pin octal plug and protected by a heat and shock resistant duct cover. Number of contacts and operational function shall be as required.
 2. Solid State Relays (SSR):
 - a) Input/output isolation: Greater than 10×10^9 ohms with a breakdown voltage of 1500V root mean square or greater at 60 Hz.
 - b) Contact Life: 10×10^6 operations or greater.

- c) Ambient Temperature Range: Minus 20 to +140 degrees F.
- d) Input impedance: Not be less than 500 ohms.
- e) Relays shall be rated for the application. Operating and release time shall be for 100 milliseconds or less. Transient suppression shall be provided as an integral part of the relay.

3. Contactors:

- a) Type: Single coil, electrically operated, mechanically held, double-break, silver-to-silver type protected by arcing contacts.
- b) Positive locking shall be obtained without the use of hooks, latches, or semi permanent magnets.
- c) The number of contacts and rating shall be selected for the application. Operating and release times shall be 100 milliseconds or less. Contactors shall be equipped with coil transient suppression devices.

2.05 SYSTEM SOFTWARE

A. General:

- 1. Provide all necessary system software to form a complete operating system for all operator interface devices.
- 2. System software shall integrate with all controller software and allow management of software applications at the operator workstation.
- 3. System software display language: English.

B. Device Profile: BACnet devices shall Conform to the following device profiles as specified in ASHRAE/ANSI 135 BACnet Annex L:

- 1. Operator workstation: BACnet Advanced Workstation (B-AWS).
- 2. Building Controller: BACnet Building Controller (B-C).
- 3. Advanced Application Controller: BACnet Advanced Application Controller (B-AAC).
- 4. Application Specific Controller: BACnet Application Specific Controller (B-ASC).

C. Software Programming:

- 1. Provide programming for the system and adhere to the sequences of operation provided. Provide actions for all possible situations. All other system programming necessary for the operation of the system shall be provided by the Contractor. Imbed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequences of operation. Provide text-based, graphic-based, and parameter-based programming where appropriate.

D. Operating System:

1. Concurrent, multi-tasking capability.
2. Common Software Applications Supported:
 - a) Microsoft Windows and Microsoft Office Suite.
 - b) Open platform compatible database: Microsoft Access, Oracle Database, IBM Analytics, or other SQL database software. Proprietary databases shall not be acceptable.
3. Acceptable Operating Systems: Most recent version of operating system.

E. System Graphics:

1. Color type, saved in an industry-standard format such as BMP, JPEG, PNG, or GIF.
2. Allow simultaneous display for comparison and monitoring of system status.
3. Web based graphics shall require no plug-in (such as HTML and JavaScript) or shall only require widely available no-cost plug-ins (such as Active-X, Java Virtual Machine, and Adobe Flash).
4. Animate displayed objects by shifting image files of objects based on object status.
5. Functionality: Provide method for operator with password to perform the following:
 - a) Move between, change size, and change location of graphic displays.
 - b) Modify on-line.
 - c) View a summary of the most important data for each controlled zone or piece of equipment.
 - d) View a summary of the most important global data for the project, including but not limited to date, day of week, time, outdoor dry bulb temperature, and humidity.
 - e) Use point-and-click navigation between graphic screens.
 - f) Edit setpoints and other specified parameters.
- a. Edit equipment names and numbers.
- b. Edit room names and numbers.
 - g) Indicate areas or equipment in an alarm condition using color or other visual indicator.
 - h) Add, delete, or change dynamic objects consisting of:
 - 1) Analog and binary values.
 - 2) Dynamic text.
 - 3) Static text.
 - 4) Animation files.
 - i) Display graphic file, text, and dynamic object data together on a single graphic. Display all measured and commanded data, setpoints, calculated values, and input and output control points with appropriate engineering units associated with each system schematic.

- j) Dynamic Data Displays: Dynamic temperature values, humidity values, flow values, and status indication shall be shown in their actual respective locations, and shall automatically update to represent current conditions without operator intervention.
 - k) Dynamic Data Displays shall be capable of including point data from multiple ASC's.
6. Include at least one graphic for each of the following:
- a) Each piece of equipment.
 - b) Occupied zone.
 - c) Hydronic system (chilled water, condenser water, hot water, steam, heat pump, etc.)
 - d) Floor plan displays of the building. Indicate summary conditions for each floor.
 - e) Indicate thermal comfort on floor plan using dynamic colors to represent zone temperature relative to zone setpoint.
2. Graphic Tree Structure:
- f) Structure graphic system tree to allow access to individual graphic screens from a macro to a micro level.
 - g) Allow each level of graphic direct access to the graphic screen above and below the graphic screen in the system tree.
 - h) Allow direct access to the main summary graphic screen/map from any individual graphic screen.
7. Sequence of Operation Graphics:
- a) Display the complete Sequence of Operation or include a link to a separate text file that contains the sequence of operation, as submitted by the Contractor and approved by the Engineer with each system schematic view. The Sequence of Operation text shall be in a separate frame above, below, or to the side of the graphic as appropriate for the graphic size and content.
8. Custom Graphics Generation Package:
- a) Allow operator to create, delete, modify, and save custom graphic files and displays. File format of graphics shall be compatible with BAS software.
 - b) Web-based Graphics: HTML graphics to support web browser compatible formats.
 - c) The BAS Contractor shall provide libraries of pre-engineered screens and symbols depicting standard components with which custom graphics may be built. Standard components include but are not limited to
 - 1) Air handling unit components (e.g., fans, cooling coils, filters, dampers, etc.).

- 2) Complete mechanical systems (e.g., constant volume-terminal reheat, VAV, etc.).
 - 3) Hydronic system components (e.g., chillers, boilers, pumps, piping, valves, etc.).
 - 4) Electrical symbols.
- d) The graphic development package shall use a mouse or similar pointing device in conjunction with a drawing program to allow the user to perform the following
- 1) Define symbols.
 - 2) Position and size symbols.
 - 3) Define background screens.
 - 4) Define connecting lines and curves.
 - 5) Locate, orient and size descriptive text.
 - 6) Define and display colors for all elements.
 - 7) Establish correlation between symbols or text and associated system points or other displays.
 - 8) Capture or convert graphics from AutoCAD.
- e) Graphical displays shall be capable of representing a group of objects. Groups shall be capable of representing any logical grouping of system points or calculated data based upon building function, mechanical system, building layout, or any other logical grouping of points which aids the operator in the analysis of the building.
3. Standard HVAC Graphics Library: Furnish a complete library of standard HVAC equipment graphics and standard symbols for ancillary equipment in a file format compatible with the graphics generation package program. Graphics shall include, but not be limited to, the following:
- a. HVAC Equipment:
 - 1) Chillers.
 - 2) Boilers.
 - 3) Air Handlers.
 - 4) Terminal HVAC Units.
 - 5) Fan Coil Units.
 - b. Ancillary Equipment:
 - 1) Fans.
 - 2) Pumps.
 - 3) Coils.
 - 4) Valves.
 - 5) Piping.
 - 6) Dampers.
 - 7) Ductwork.

F. Workstation System Applications:

1. General Application Functions:
 - a) All applications shall be capable of being executed automatically without the need for operator intervention, and shall be flexible enough to allow user customization.
 - b) Allow BAS configuration and future changes or additions by operators with password protection.
 - c) Execute configured processes defined by the user to automatically perform calculations and control routines.
 - d) Process Inputs and Variables: It shall be possible to use any of the following in a configured process:
 - 1) Any system-measured point data or status
 - 2) Any calculated data
 - 3) Any results from other processes
 - 4) Boolean logic operators (and, or)
 - e) Process Triggers: Configured processes may be triggered based on any combination of the following:
 - 1) Time of day
 - 2) Calendar Date
 - 3) Other processes
 - 4) Events (e.g., point alarms)
 - f) Data Access: A single process shall be able to incorporate measured or calculated data from any and all other ASC's. In addition, a single process shall be able to issue commands to points in any and all other ASC's on the local network.
2. Network Configuration:
 - a) Allow for configuration of the BAS network.
 - b) Provide alarm when a break in communication between devices is detected.
 - c) Enable the operator to add, delete, or modify the following:
 - 1) Building controllers and ASC's.
 - 2) Points of any type, point parameters, and tuning constants.
 - d) Provide automatic reconfiguration if any station is added or lost.
3. Save and Restore:
 - a) Automatic System Database Save and Restore Functions:
 - 1) Store current database copy of each Building Controller on hard disk or server.
 - 2) Backup database on a user adjustable frequency basis. Default frequency shall be monthly.
 - 3) Automatically update upon change in any system panel.

- 4) In the event of database loss in any system panel, the first workstation to detect the loss automatically restores the database for that panel unless disabled by the operator.
- b) Manual System Database Save and Restore Functions by Operator with Password Clearance:
 - 1) Save database from any system panel.
 - 2) Clear a panel database.
 - 3) Initiate a download of a specified database to any system panel.
4. On-line Help:
 - a) Include context-sensitive system to assist operator in operation and editing.
 - b) Include topics available for all applications.
 - c) Include relevant screen data provided for particular screen display.
 - d) Include additional help via hypertext.
5. Security:
 - a) Require user name and password for Operator log-on to view, edit, add, or delete data.
 - b) Include selectable system security for each operator. Support a minimum of five levels of access:
 - 1) Level 1 = Read-only data access and display.
 - 2) Level 2 = Level 1 + scheduling.
 - 3) Level 3 = Level 2 + operator overrides and commands.
 - 4) Level 4 = Level 3 + database generation and modification.
 - 5) Level 5 = Level 4 + Audit trail management.
 - 6) Operators shall be able to perform only those commands available for their respective passwords. Menu selections displayed at any operator device shall be limited to only the items defined as accessible for the user.
 - 7) Support a minimum of 4 passwords at each Building Controller.
 - c) Allow system supervisor to set passwords and security levels for all other operators.
 - d) Allow operator passwords to restrict functions accessible to viewing and/or changing system applications, editor, and object.
 - e) Include automatic, operator log-off results from keyboard or mouse inactivity during user-adjustable, time period.
 - f) Store all system security data in encrypted format.
 - g) Log all user actions and store data for audit with permission access by system administrator only.
 - 1) Include the modified system.
 - 2) Include the value modified.

- 3) Include the time of modification.
6. System Diagnostics:
 - a) Operations Automatically Monitored:
 - 1) Workstations.
 - 2) Printers.
 - 3) Network connections.
 - 4) Building management panels.
 - 5) Controllers.
 - b) Device failure is annunciated to the operator.
 7. Alarm Management:
 - a) Allow alarm prioritizing to minimize nuisance reporting and to speed operator response to critical alarms.
 - 1) Provide a minimum of three, user definable priority levels.
 - 2) Enable users to manually inhibit alarm reporting for each point.
 - 3) Enable users to manually inhibit nuisance alarm reporting for maintenance or repair work that is scheduled to be performed.
 - 4) Enable user to define conditions under which point changes need to be acknowledged by an operator, and/or logged for analysis at a later date.
 - 5) Allow alarm prioritization to lock out or circumvent other alarms that may be generated as a result of primary alarm.
 - b) Prohibit interference with the ability of the system software to report alarms by either operator activity at the local I/O device, or communications with other system controllers on the network.
 - c) Allow all system objects that are configurable to "alarm in" and "alarm out" of normal state.
 - d) Configurable Objects:
 - 1) Alarm limits.
 - 2) Alarm limit differentials.
 - 3) States.
 - 4) Reactions for each object.
 - 5) Alarm delay.
 - e) Alarm Messages:
 - 1) Descriptor: English language. Acronyms or mnemonics for objects in alarm are not acceptable.
 - 2) Recognizable Features:
 - a) Source.
 - b) Location.
 - c) Nature.

- d) Time and Date.
 - e) Alarm message box to more fully describe the alarm condition or direct operator response.
 - f) Each Alarm messages shall be assignable to any point in the BAS. Alarm messages shall be assignable to multiple points.
 - a) Notification of an alarm override.
 - f) Configurable Alarm Reactions by Workstation and Time of Day:
 - 1) Logging.
 - 2) Printing.
 - 3) Starting programs.
 - 4) Displaying messages.
 - 5) Phone text message.
 - 6) Email.
 - 7) Providing audible annunciation.
 - 8) Displaying specific system graphics.
8. Custom Trend Logs:
- a) Maintain trend information for minimum 365 days.
 - b) Definable for any data object in the system including interval, start time, and stop time.
 - 1) Resolution: Interval periods shall be adjustable down to one minute.
 - 2) Multiple Interval Period: Each trended point shall have the ability to be trended at a different trend interval.
 - c) Trend Data:
 - 1) Sampled and stored on the building controller panel.
 - 2) Auto-Delete Period: Software shall be capable of automatically deleting stored trend data after a user-adjustable period of time. Each trended point shall have the ability to have a different auto-delete interval period.
 - 3) Archivable on hard disk or server.
 - 4) Retrievable for use in reports, spreadsheets and standard database programs.
 - 5) Protected and encrypted format to prevent manipulation or editing of historical data and event logs.
 - d) Trend Graph Display:
 - 1) Group Trend Time Series Plots:
 - a) Provide user-selectable Y-axis points.
 - b) Provide user editable titles, point names, and Y-axis titles.

- c) Individual trended points shall be able to be grouped into groups of up to four points per plot with up to four plots per page.
 - 2) X-Y Trend Plots:
 - a) User selectable X and Y trend inputs.
 - b) User editable titles, point names, and X and Y-axis titles.
 - c) User selectable time period options:
 - i) 1-day 24-hour period.
 - ii) 1-week 7-day period.
 - iii) 1-month period with appropriate days for the month selected.
 - iv) 1-year period.
 - v) User shall be able to select the beginning and ending period for each X-Y chart, within the time domain of the database being used.
 - vi) User selectable display up to 6 plots per screen in 2 columns.
 - 3) Automatic Scaling: System shall automatically scale the axis on which trends are displayed when multiple points with different trend interval periods are selected for graphical display.
 - 4) Dynamic Update: Trends shall be able to dynamically update at operator-defined intervals.
 - 5) Zoom: Software shall allow zoom-in function for detailed examination of trends.
 - e) Numeric Value Display: Software shall display value of any sample on a trend when picked.
- 9. Alarm and Event Log:
 - a) View all system alarms and change of states from any system location.
 - b) List events chronologically.
 - c. List alarm priority.
 - c) Allow operator with proper security to acknowledge and clear alarms. Log operator and time when alarm is acknowledged.
 - d) Archive alarms not cleared by operator to the workstation.
- 10. Object, Property Status, and Control:
 - a) Provide a method to view, edit if applicable, the status of any object and property in the system.
 - b) Status Available by the Following Methods:
 - 1) Menu.
 - 2) Graphics.

- 3) Custom Programs.
11. Clock Synchronization:
 - a) The real-time clocks in all building control panels and workstations shall be able to automatically synchronize daily from any operator-designated device in the system.
 - b) The system shall automatically adjust for daylight savings and standard time, if applicable.
 12. Reports and Logs:
 - a) Reporting Package:
 - 1) Allow operator to select, modify, or create reports.
 - 2) Definable as to data content, format, interval, and date.
 - 3) Under no conditions shall the operator need to specify the address of hardware controller to obtain system information.
 - 4) Provide ability to obtain real-time logs of all objects available by type or status such as alarm, lockout, normal, etc.
 - 5) Stored on hard disk and readily accessible by standard software applications, including spreadsheets and word processing.
 - 6) Allow printing on operator command or specific time(s).
 - b) Standard Report Format Options:
 - 1) Objects with current values.
 - 2) Global modification values.
 - 3) Current alarms not locked out.
 - 4) Disabled and overridden objects, points and variables.
 - 5) Objects in manual or automatic alarm lockout.
 - 6) Objects in alarm lockout currently in alarm.
 - 7) Objects currently in override status.
 - 8) Objects in Schedules
 - a) Daily.
 - b) Weekly.
 - c) Holiday.
 - 9) Logs:
 - a) Alarm History.
 - b) System messages.
 - c) System events.
 - d) Trends.
 - c) Custom Report Format Options:
 - 1) Daily.
 - 2) Weekly.
 - 3) Monthly.

- 4) Annual.
 - 5) Time and date stamped.
 - 6) Title.
 - 7) Facility name.
 - 8) Point Groups.
 - a) User-selectable.
 - b) Group may be comprised of specific points, group of equipment objects, group of groups, or for the entire facility without restriction due to the hardware configuration of the BAS.
 - d) Electrical, Fuel, and Weather:
 - 1) Electrical Meter(s):
 - a) Monthly showing daily electrical consumption and peak electrical demand with time and date stamp for each meter.
 - b) Annual summary showing monthly electrical consumption and peak demand with time and date stamp for each meter.
 - 2) Fuel Meter(s):
 - a) Monthly showing daily fuel consumption for each meter.
 - b) Annual summary showing monthly consumption for each meter.
 - 3) Weather:
 - a) Monthly showing minimum, maximum, average outdoor air temperature and heating/cooling degree-days for the month.
 - e) Daily Operating Condition of Chiller(s): Program a daily report that shows the operating condition of each chiller as recommended by ASHRAE Standard 147. Reference the control drawings for the points that shall be included in the log report.
13. Global Modify:
- a) Allow global modification of all editable data. Similar data shall be grouped into logical objects based on building function, mechanical system, building layout, or any other logical grouping of points.
 - b) Allow each common type of equipment to be excluded or included within the global editing process.
 - c) Display status information on all similar points in one global report.
 - d) Allow modification of the following:
 - 1) Individual data point edited.
 - 2) List of all points within the category.

- 3) Global change field.
 - 4) Copy feature to assist in downloading the new changes.
 - 5) Verification that all changes were completed.
- e) Include a change-all feature to change all selections.
 - f) Prevent acceptance of changes until an accept icon is acknowledged.

G. Workstation Applications Editors:

1. Provide editing software for each system application at the PC workstation.
2. Edited applications shall be automatically downloaded and executed at the controller panel.
3. Programming Description: Definition of operator device characteristics, ASC's, individual points, applications and control sequences shall be performed through fill-in-the-blank templates.
4. System Definition/Control Sequence Documentation: All portions of system definition shall be self-documenting to provide hard copy printouts of all configuration and application data.
5. System definition and modification procedures shall not interfere with normal system operation and control.
6. Provide consistent text-based displays of all system point and system applications.
7. Point identification, engineering units, status indication, and application naming conventions shall be the same at all operator devices.
8. Full screen editor for each application shall allow operator to view and change:
 - a) Configuration.
 - b) Name.
 - c) Control parameters.
 - d) Set-points.
 - e) Schedules.
9. Scheduling:
 - d. Allow scheduling down to the zone or room level.
 - a) Monthly calendar indicates schedules, holidays, and exceptions.
 - b) Allows several related objects to be grouped, scheduled, and copied to other objects or dates.
 - c) Start and stop times adjustable from master schedule.
 - e. Schedule expiration.
 - d) Temporary overrides of systems with user adjustable time-out.
 - f. Provide minimum three tiers of priorities for scheduling.
 - 1) Priority 1: Event, temporary, or override.
 - 2) Priority 2: Calendar.
 - 3) Priority 3: Default.

- g. Higher priority schedules shall overlay with lower priority schedules without interrupting or deleting them. Upon expiration of a higher priority schedule, schedule shall revert to next lower priority.
 - h. Expired priority 1 and priority 2 schedules shall be automatically deleted after execution.
10. Custom Application Programming:
- a) Create, modify, debug, edit, compile, and download custom application programming during operation and without disruption of all other system applications.
 - b) Programming Features:
 - 1) English oriented programming language, allowing for free form programming.
 - 2) Alternative language graphically based using appropriate function blocks suitable for all required functions and amenable to customizing or compounding.
 - 3) Insert, add, modify, and delete custom programming code that incorporates word processing features such as cut/paste and find/replace.
 - 4) Allows the development of independently, executing, program modules designed to enable and disable other modules.
 - 5) Debugging/simulation capability that displays intermediate values and/or results including syntax/execution error messages.
 - 6) Support for conditional statements (IF/THEN/ELSE/ELSE-F) using compound Boolean (AND, OR, and NOT) and/or relations (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.
 - 7) Support for floating-point arithmetic utilizing plus, minus, divide, times, square root operators; including absolute value; minimum/maximum value from a list of values for mathematical functions.
 - 8) Language consisting of resettable, predefined, variables representing time of day, day of the week, month of the year, date; and elapsed time in seconds, minutes, hours, and days where the variable values can be used in IF/THEN comparisons, calculations, programming statement logic, etc.
 - 9) Language having predefined variables representing status and results of the system software enables, disables, and changes the set points of the controller software.

2.06 CONTROLLER SOFTWARE

- A. All applications reside and operate in the system controllers and editing of all applications occurs at the operator workstation.
- B. System Security:
 - 1. User access secured via user passwords and user names.
 - 2. Passwords restrict user to the objects, applications, and system functions as assigned by the system manager.
 - 3. User Log On/Log Off attempts are recorded.
 - 4. Automatic Log Off occurs following the last keystroke after a user defined delay time.
- C. Object or Object Group Scheduling:
 - 1. Weekly Schedules Based on Separate, Daily Schedules:
 - a) Include start, stop, optimal stop, and night economizer.
 - b) 10 events maximum per schedule.
 - c) Start/stop times adjustable for each group object.
 - 2. Exception Schedules:
 - a) Based on any day of the year.
 - b) Defined up to one year in advance.
 - c) Automatically discarded and replaced with standard schedule for that day of the week upon execution.
 - 3. Holiday or Special Schedules:
 - a) Capability to define up to 99 schedules.
 - b) Repeated annually.
 - c) Length of each period is operator defined.
- D. System Coordination: Provide a standard application for equipment coordination. The application shall provide the operator with a method of grouping together equipment based on function and location. Groups shall be capable of being used for scheduling and other applications.
- E. Alarms:
 - 1. Binary object is set to alarm based on the operator specified state.
 - 2. Analog object to have high/low alarm limits.
 - 3. All alarming is capable of being automatically or manually disabled.
 - 4. Alarm Reporting:
 - a) Operator determines action to be taken for alarm event.
 - b) Alarms to be routed to appropriate workstation.
 - 5. Reporting Action Options:
 - a) Start Programs.

- b) Print.
 - c) Logged.
 - d) Custom messaging.
 - e) Graphical displays.
 - f) Dial out to workstation receivers via system protocol.

- F. Maintenance Management: System monitors equipment status and generates maintenance messages based upon user-designated run-time limits.

- G. Sequencing: Application software based upon specified sequences of operation on the control drawings.

- H. PID Control Characteristics:
 - 1. Provide proportional-integral algorithms.
 - 2. Direct or reverse action.
 - 3. Anti-windup.
 - 4. Calculated, time-varying, analog value, positions an output or stages a series of outputs.
 - 5. User selectable controlled variable, set-point, and PI gains.

- I. Staggered Start Application:
 - 1. Prevents all controlled equipment from simultaneously restarting after power outage.
 - 2. Order of equipment startup is user selectable.

- J. Anti-Short Cycling:
 - 1. All binary output objects protected from short-cycling.
 - 2. Allows minimum on-time and off-time to be selected.
 - 3. Allows the number of times each piece of equipment may be cycled within any one-hour period.

- K. On-Off Control with Differential:
 - 1. Algorithm allows binary output to be cycled based on a controlled variable and set-point.
 - 2. Algorithm to be direct-acting or reverse-acting incorporating an adjustable differential.

- L. Trending: Building controllers shall allow collection and delivery of (time, value) pairs.

- M. Totalization:
 - 1. Run-Time Totalization:
 - a) Totalize run-times for all binary input objects.
 - b) Provides operator with capability to assign high run-time alarm.

- c) Generates unique, user-specified messages when the limit is reached.
 - d) Resolution: Adjustable down to one minute.
2. Pulse Totalization:
- a) Totalize consumption for user-selected analog and binary pulse input-type objects.
 - b) Configurable for a daily, weekly, or monthly basis.
 - c) Provide calculation and storage accumulations of up to 9,999,999 units (e.g. KWH, gallons, KBTU, tons, etc.).
 - d) Resolution: Adjustable down to one minute.
 - e) Warning Limit: User definable. Generate unique, user-specified messages when the limit is reached.
 - f) The information available from the Pulse Totalization shall include, but not be limited to, the following:
 - 1) Peak Demand, with date and time stamp
 - 2) 24-hour Demand Log
 - 3) Accumulated KWH for day
 - 4) Sunday through Saturday KWH usage
 - 5) Sunday through Saturday Demand kW
 - 6) Demand kW annual history for past 12 periods
 - 7) KWH annual history for past 12 periods
3. Event Totalization:
- a) Count user-selected events, such as the number of times a pump or fan system is cycled on and off.
 - b) Provide storage accumulations of up to 9,999,999 events before reset.
 - c) Warning Limit: User definable. Generate unique, user-specified messages when the limit is reached.

PART 3 - EXECUTION

3.01 EXAMINATION

- A. Verify existing conditions before starting work.
- B. Verify that systems are ready to receive work.
- C. Beginning of installation means installer accepts existing conditions.
- D. Verify that conditioned power supply is available to the control units and to the operator work station. Verify that field end devices and wiring are installed prior to installation proceeding.
- E. Verify the integrity of control wiring, raceways, control panels, sensors, and control devices prior to reusing for the new work.

- F. Verify wiring insulation is defect free and test wiring for continuity and ground faults.

3.02 INSTALLATION

- A. Install products in accordance with manufacturer's instructions.

- B. Coordination:

1. Cooperate with other contractors performing work on this project as necessary to achieve a complete and coordinated installation. Each Contractor shall consult the Drawings and Specifications for all trades to determine the nature and extent of others work.
2. Coordinate with the Owner to display additional virtual points on individual schematic graphic screens that are not directly associated with that system. Examples may include outdoor air temperature or global alarm conditions.

- B. Web Services Enabled Network:

3. Provide an IP network data drop for connection of BAS into Owner's IP network. Coordinate final location of IP network data drop with the Owners' IT staff.
4. If the Owner has no preference or not indicated on the drawings, locate data drop within the main BAS control panel.
5. Coordinate with the Owner's IT department to implement proper security measures, including secure access to the network data drop and firewalls at all virtual access points to the internet to protect access to the BAS.

- C. General Workmanship:

1. Install equipment, piping, and wiring/raceway parallel to building lines wherever possible.
2. Install all equipment in readily accessible locations.
3. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.
4. All installations shall comply with industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.
 6. Control wiring routed in wall cavities shall be installed in conduit.
 7. Install control units and other hardware in position on permanent walls where not subject to excessive vibration.
 8. Install software in control units and in operator work station. Implement all features of programs to specified requirements and appropriate to sequence of operation.

- C. Controllers:

1. Install controllers in a locked control panel. Provide common keying for all controller covers.

2. Provide a separate controller for each piece of controlled equipment, such as an AHU, FCU, VAV box, etc. A controller may control more than one piece of equipment provided that all points associated with the equipment are assigned to the same BAS controller. Global points used for control loop reset are exempt from this requirement.
3. Select building controllers and custom application controllers to provide the required I/O point capacity required to monitor all of the hardware points listed on the control drawings.
4. Application specific controllers may be used where factory programming is capable of executing all control functions specified in the sequences of operation. Contractor shall add supplemental controllers, devices, and programming as required to execute the specified control function if the ASC cannot.

D. Wiring:

1. All control and interlock wiring shall comply with national and local electrical codes.
5. Properly ground all controllers.
6. Wire all safety devices through both hand and auto positions of motor starting device to ensure 100 percent safety shut-off.
 2. Provide interlock wiring between devices as indicated on the control drawings.
 3. Provide electrical wiring for relays (including power feed) for temperature and pressure indication.
 4. All NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway according to NEC and Division 26 requirements.
 5. All low-voltage wiring shall meet NEC Class 2 requirements. Low-voltage power circuits shall be sub-fused when required to meet Class 2 current limit.
7. Conceal all low voltage wiring in finished rooms.
8. Conceal all low voltage wiring in unfinished rooms below the elevation of the lights. Low voltage wiring above the elevation of the lights may be exposed.
9. Routing of low voltage wiring above working heights in equipment rooms and above accessible ceilings is acceptable subject to following criteria:
 - a. Wiring shall be plenum rated.
 - b. Do not lay wiring on ceiling tiles.
 6. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL listed for the intended applications.
 7. All wiring in mechanical, electrical, service rooms, or where subject to mechanical damage, shall be installed in raceway at levels below 10 feet.
 8. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high voltage wiring and equipment may not be used

- for low-voltage wiring except for the purpose of interfacing the two wires (e.g., relays and transformers).
9. Where Class 2 wiring is run exposed, wiring shall be run parallel along a surface or perpendicular to it and neatly tied at 10 foot intervals.
 10. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems.
 11. All wire-to-device and wire-to-wire connections shall be made at a terminal block or terminal strip.
 12. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
 13. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, coordinate with Division 26 to provide step-down transformers.
 14. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.
 15. Install plenum wiring in sleeves where it passes through floors and walls. Maintain fire rating at all penetrations.
 16. Size of raceway and size and type of wire shall be the responsibility of the Contractor, in keeping with the manufacturer's recommendations and NEC requirements, except as noted elsewhere.
 17. Include one pull string in each raceway 1 inch and larger.
 18. Use coded conductors throughout with conductors of different colors.
 19. Control and status relays shall be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.
 20. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 6 inches from high-temperature equipment (e.g., steam pipes or flues).
 21. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.
 22. Install insulated bushing on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.
 23. Terminate all control and/or interlock wiring and maintain updated (as-built) wiring diagrams with terminations identified at the job site.
 24. Terminate BAS sensor input wiring cable shield by taping back at the field device and connect shield to the grounded control panel chassis or sub-panel.
 25. Terminate BAS comm bus cable shield between controllers per manufacturer recommendations.
 26. Terminate management level/enterprise level network wiring cable shield by wrapping the drain wire around the foil shield and connecting the ground strip to the drain wire.

27. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 3 feet in length and shall be supported at each end. Flexible metal raceway less than 1/2 inch electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.
28. Raceway shall be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations shall be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

E. Communication Wiring:

1. Adhere to the items listed in the “Wiring” article in Part 3 of this specification in addition to the requirements listed below.
2. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer’s installation recommendations for all communication wiring.
3. Do not exceed 328 feet in Ethernet wiring length between switches or repeaters.
4. Do not install communication wiring in raceway and enclosures containing Class 1 or other Class 2 wiring.
5. Do not install power wiring, in excess of 30 Vac RMS, in conduit with communications wiring. In cases where signal wiring is run in conduit with communication wiring, use separate twisted shielded pairs with the shields grounded in accordance with the manufacturer’s wiring practice.
6. Communication conduits shall not be installed closer than six feet from high power transformers or run parallel within six feet of electrical high power cables. Care shall be taken to route the cable as far from interference generating devices as possible.
7. Do not exceed maximum pulling, tension, and bend radius for cable installation, as specified by the cable manufacturer during installation.
8. Verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.
9. When a cable enters or exits a building, install a lightning arrestor between the lines and ground. Install the lightning arrestor according to the manufacturer’s instructions.
10. Ground (earth ground) all shields at one point only, to eliminate ground loops.
11. All runs of communications wiring shall be unspliced length when that length is commercially available.
12. Terminate shielded cable splices in accessible locations. Harness cables with cable ties.
13. Make all wire-to-device and wire-to-wire connections at a terminal block or terminal strip.
14. Label all communications wiring to indicate origination and destination data.
15. Ground coaxial cable in accordance with NEC regulations.

16. Install BACnet MS/TP communications wiring in accordance with ASHRAE/ANSI Standard 135
 - a) The network shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 17 pF per foot at 76,800 Baud.
 - b) The maximum length of an MS/TP segment shall be 3000 ft with AWG 22 or 24 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485.
 - c) The maximum number of nodes per segment shall be 50. Additional nodes may be accommodated by the use of repeaters.
 - d) An MS/TP EIA-485 network shall have no T connections.

F. Fiber Optic Cable System:

1. Do not exceed maximum pulling, tension, and bend radius for cable installation, as specified by the cable manufacturer during installation.
2. Install all cabling and associated components in accordance with manufacturer's instructions. Maintain minimum cable and unjacketed fiber bend radii, as specified by cable manufacturer.

G. Identification of Hardware and Wiring:

1. Label all wiring and cabling, including that within factory-fabricated panels, at each end within 2 inch of termination with the BAS address or termination number.
2. Permanently label or code each point of field terminal strips to show the instrument or item served.
3. Identify control panels with minimum 1/2 inch letters on laminated plastic nameplates.
4. Identify all other control components with permanent labels. Label all plug-in components such that removal of the component does not remove the label.
5. Identify room sensors related to terminal box or valves with nameplates.
6. Maintain manufacturers' nameplates and UL or CSA labels visible and legible after equipment is installed.
7. Identifiers shall match record documents.

3.03 STARTUP AND DEMONSTRATION

- A. Start and commission systems. Allow sufficient time for start-up and commissioning prior to placing the BAS in permanent operation.
- B. Contractor shall provide an on-site controls technician or programmer familiar with the project BAS installation and system programming to assist the Commissioning Agent as directed during all phases of system functional testing.

- C. Coordinate with Owner the setup of logins, passwords, and security level access for individuals requiring access to the BAS.
- D. BAS graphics shall be updated with final equipment names, equipment numbers, room names and room numbers to match the final construction documents and any Owner changes made prior to occupancy.
- D. BAS shall be set up and checked by factory trained technicians skilled in the setting and adjustment of the BAS equipment used in this project. Technicians shall be experienced in the type of HVAC systems associated with this project.
- E. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
- F. Test each control device to ensure that it is operating properly and is calibrated to the appropriate operating requirements. Run each control device through its range of operation and sequence. Verify all normal positions are correct. Adjust and tune PID control constants to achieve proper system operation.
 - 1. As each control input and output is checked, a log shall be completed showing the date, technician's initials, and any corrective action taken or needed.
 - 2. Demand limiting. The Contractor shall supply a trend data output showing the action of the demand limiting algorithm. The data shall document the action on a minute-by-minute basis over at least a 30-minute period. Included in the trend shall be building kW, demand limiting set point, and the status of sheddable equipment outputs.
 - 3. Optimum start/stop. The Contractor shall supply a trend data output showing the capability of the algorithm. The change-of-value or change-of-state trends shall include the output status of all optimally started and stopped equipment, as well as temperature sensor inputs of affected areas.
 - 4. Any tests that fail to demonstrate the operation of the BAS shall be repeated at a later date. The Contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.
- G. Test and verify control interfaces to other building systems integrated into the network.
- H. Verify all alarms and interlocks.
 - 1. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
 - 2. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
 - 3. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action.

4. Verify fire/smoke and smoke damper functionality. Verify that they respond to the proper fire alarm system general, zone, and/or detector trips.
- I. Document on system equipment schedules the final setting of controller PID constant settings, setpoints, manual reset values, maximum and minimum controller output, and ratio and bias settings in units and terminology specific to the controller. Store documentation with operator workstation.
 - J. Demonstrate complete and operating system to Owner.
 1. Prior to acceptance, the BAS shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.
 2. The tests described in this section are to be performed in addition to the tests that the Contractor performs as a necessary part of the installation, start-up, and debugging process.
 3. The Contractor shall demonstrate actual field operation of each control and sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. Any test equipment required to provide the proper operation shall be provided by and operated by the Contractor.
 4. Demonstrate compliance with sequences of operation through all modes of operation.
 5. Demonstrate complete operation of operator interface.
 - K. Acceptance:
 1. All tests described in this specification shall have been performed to the satisfaction of the Owner prior to the acceptance of the BAS as meeting the requirements of completion. Any tests that cannot be performed due to circumstances beyond the control of the Contractor may be exempt from the completion requirements if stated as such in writing by the Contractor and submitted for approval by the Owner. Such tests shall then be performed as part of the warranty.
 2. The BAS shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved.

3.04 MAINTENANCE SERVICE

- A. Provide service and maintenance of energy management and control systems for one year from Date of Substantial Completion.

3.05 TRAINING

- A. General: At a time mutually agreed upon between the Owner and Contractor, provide the services of a factory trained and authorized representative to train

Owner's designated personnel for a minimum of sixteen hours on the operation and maintenance of the equipment provided under this section.

- B. Organize the training into sessions or modules for different levels of operators. Owner designated personnel shall be trained based on the level of operator training described below.
- C. Day-to-day Operator Training:
 - 1. Overview of the system and/or equipment as it relates to the facility as a whole.
 - 2. Proficiently operate the BAS.
 - 3. Understand BAS architecture and configuration.
 - 4. Understand BAS components.
 - 5. Understand system operation, including BAS control and optimizing routines (algorithms).
 - 6. Operate the workstation and peripherals.
 - 7. Log on and off the system.
 - 8. Access graphics, point reports, and logs.
 - 9. Adjust and change system set points, time schedules, and holiday schedules.
 - 10. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals.
 - 11. Understand BAS drawings and Operation and Maintenance manual.
 - 12. Understand the job layout and location of control components.
 - 13. Access data from BAS controllers and ASCs.
 - 14. Operate portable operator's terminals.
 - 15. Operation and maintenance procedures and schedules related to startup and shutdown, troubleshooting, servicing, preventive maintenance and appropriate operator intervention.
- D. Review data included in the operation and maintenance manuals. Refer to Division 1 Section "Operation and Maintenance Data."
- E. Certification: Contractor shall submit to the Engineer a certification letter stating that the Owner's designated representative has been trained as specified herein. Letter shall include date, time, attendees and subject of training. The certification letter shall be signed by the Contractor and the Owner's representative indicating agreement that the training has been provided.
- F. Schedule: Schedule training with Owner with at least 7 days' advance notice.

END OF SECTION

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