SECTION 230900 - INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes control equipment, including but not limited to HVAC systems and components, control components for equipment not supplied with factory-wired controls.

B. Direct-Digital Control (DDC) system description
   1. The Controls Contractor shall supply and install a complete Direct Digital Control (DDC) Building Automation System (BAS) as required to accomplish the Sequences of Control for heating, ventilating, air-conditioning and other building-level equipment and systems as described herein.

C. Furnish all labor, materials, equipment and service necessary for a complete and operational DDC BAS pursuant with this specification and as shown on the associated contract drawings.

D. Provide all labor, material, equipment and service not specifically referred to in this specification or on associated drawings that are required to fulfill the functional intent of this specification at no additional cost to the Owner.

1.2 DEFINITIONS

A. B-AAC: Advanced Application Controllers

B. B-ASC: Application Specific Controllers

C. ATC: Automatic Temperature Control

D. BAS: Building Automation System

E. B-AWS: Advanced Workstation Software

F. B-OWS: Operator Workstation Software

G. B-BC: Building Controllers

H. BTN: BACnet Testing Laboratories

I. DDC: Direct digital control.

J. HLC: Heavy load conditions.

K. I/O: Input/output.

L. MS/TP: Master slave/token passing.

M. PC: Personal computer.

N. PID: Proportional plus integral plus derivative.

O. RTD: Resistance temperature detector.

1.3 CODES

A. Comply with all applicable current codes, ordinances, and regulations.

1.4 REFERENCE STANDARDS

A. The latest published edition of a reference shall be applicable to this Project unless identified by a specific edition date.

B. All materials, installation and workmanship shall comply with the applicable requirements and standards addressed within the following references:
   1. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)
      a. ANSI/ASHRAE Standard 135, BACnet
      b. ASHRAE Guideline 36, High-Performance Sequences of Operation for HVAC Systems
   2. American National Standards Institute (ANSI)
   3. UL 916: Energy Management Systems
   4. BACnet Testing Lab

1.5 DDC SYSTEM REQUIREMENTS

A. DDC Systems installed under this specification shall strictly adhere to the following characteristics:
   1. Building Automation System (BAS) Direct Digital Controls (DDC) shall consist of native BACnet, microprocessor-based, peer-to-peer, networked, distributed devices utilizing the BACnet communication protocol in an open, interoperable system. The BAS also includes operator interface devices, programming and configuration software applications, DDC input/output devices, non-DDC automatic temperature controls, enclosures and interconnecting conduit and wire.
      a. The BACnet operating stack must be embedded directly in every Device at the board level, and in all operator interface software packages.
      b. No Gateways, Communication Bridges, Protocol Translators or any other device that translates any proprietary or other communication protocol to the BACnet communication protocol shall be permitted as a part of the BAS installation pursuant with this specification section. Gateways may only be used as required for communication to existing systems or systems installed pursuant with other specification sections.
      c. DDC controllers that are not BACnet compliant shall not be acceptable under this specification and are strictly prohibited.
      d. The Owner shall receive ownership of all job specific configuration documentation, data files, programming tools, 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 B-BC, BAS Server, and any related LAN / WAN / Intranet and Internet connected routers and devices. Any and all required IDs and passwords for admin and programming level access to any component or software program shall be provided to the Owner.
   2. The BAS shall be modular in nature and comprised of a network of stand-alone DDC devices. The System shall be designed and implemented in such a way that it may be expanded in both capacity and functionality through the addition of DDC Devices, sensors, actuators, etc.
   3. All BAS controllers shall be tested, certified, and clearly stamped and listed by the BACnet Testing Laboratories (BTL).

4. Program database, data acquisition, and all control sequence logic shall reside in each DDC Device. The BAS shall not be dependent upon connection to a Server or Master Controller for performance of the Sequence of Control as outlined in this specification. Each individual Device shall, to the greatest possible extent, perform its programmed sequence without reliance on the BAS network.
5. All BAS DDC Devices at all levels shall be fully custom-programmable in the field using the standard Operators Workstation Software. No configurable, canned program application specific controllers will be permitted.
6. All BAS DDC Devices shall be capable of updating firmware using software via internet without replacing any hardware, microprocessors or chips.
7. The BAS shall be capable of sending system alarms and Event Notifications to pagers, and email services.
8. Actuation of control devices shall be electronic. Spring return fail-safe actuation shall be provided when loss of property and/or property damage is possible and where specified.
9. DDC Automatic Temperature Control (ATC) System shall prevent all controlled equipment from simultaneously restarting after a power outage. The order in which equipment (or groups of equipment) is started; along with the time delay between starts shall be user-selectable.
10. All binary output points shall be protected from short cycling via output configuration and/or programming. This feature shall allow minimum on time and off-time to be configurable.
11. The DDC System Manufacturer product line selected shall be the most current and complete offering from the manufacturer and shall currently be actively manufactured and supported at the time that this project is bid.
12. This project shall not be used as a test site. First release and test version hardware, software and firmware shall not be implemented on this project under any circumstances.
13. DDC System devices and spare components or equivalent shall be readily available for a minimum of five (5) years after the completion and final acceptance of this project.

1.6 WEB ACCESS

A. DDC system to be web based.
   1. Web-Based Access to DDC System:
      a. DDC system software based on server thin-client architecture, designed around open standards of web technology. DDC system server accessed using a web browser over DDC system network, using Owner's LAN, and remotely over Internet through Owner's LAN.
      b. Intent of thin-client architecture is to provide operators complete access to DDC system via a web browser. No special software other than a web browser is required to access graphics, point displays, and trends; to configure trends, points, and controllers; and to edit programming.
      c. Password-protected web access.

1.7 BASIC SYSTEM ARCHITECTURE

A. The DDC BAS as provided and installed under this specification shall be a complete system from a single manufacturer designed for use on intranets and the internet.

B. The BAS shall consist of a 4-Tier network architecture.

1. Tier 1: Enterprise IP Network
   a. Enterprise LAN to host Advanced Operators Workstations (B-AWS), Web-Enabled remote connectivity, client computers, and printers.
2. Tier 2: Building Infrastructure
   a. High-speed BACnet/IP Local Area Network (LAN) to host Building Controllers (B-BC), Network Infrastructure devices, communications, and wiring.
   b. The building infrastructure provides the connectivity to which networked control device connect. The Tier 2 devices shall be connected to the network via Ethernet IP.
3. Tier 3: Equipment Level
   a. Serial communication network to host field level DDC controllers such as Advanced Application Controllers (B-AAC), and Application Specific Controllers (B-ASC).
   b. The equipment level controllers are connected to the Tier 2 BAS devices via RS-485 serial communication.
4. Tier 4: End Devices
   a. Physical control device I/O such as field sensors and actuators.
   b. The end devices are connected to the Tier 3 BAS devices via hardwired I/O.

C. The primary BAS components shall include but not be limited to:
   1. BACnet Advanced Operator Workstation Software (B-AWS)
   2. Remote BACnet Advanced Operator Workstation Software (Remote B-AWS)
   3. Portable Operator Workstation Software (Portable B-OWS)
   4. Building Controllers (B-BC)
   5. Advanced Application Controllers (B-AAC)
   6. Application Specific Controllers (B-ASC)

D. B-BCs shall automatically route BACnet communications to all configured available BACnet networks.

E. B-AWS shall be fully IT-compatible devices that communicate directly on a TCP/IP Local Area Network (LAN).
   1. LAN shall be 10/100/1000Mbps TCP/IP with the following minimum requirements:
      a. Cable: 1000 base-T, UTP-8 wire, category 6 or greater
      b. Minimum throughput: 10Mbps with the ability to increase to 1000Mbps
   2. The Tier 1 Network shall provide communication between B-BCs, B-OWS, remote B-OWS and Web Server using a B/IP LAN backbone.
   3. B-BCs shall connect directly to the LAN and communicate using B/IP without a TCP/IP Gateway or network server.
   4. Coordinate implementation of the BAS on the Owner's LAN without disruption.

F. BAS Manufacturer must natively support the following BACnet data links as defined in the ANSI/ASHRAE Standard 135-2024, BACnet:
   1. Point-to-Point (PTP)
   2. Master Slave/Token Passing (MS/TP)
   3. Ethernet (ISO 8802-3)
   4. BACnet IP (B/IP)

G. Special Network Architecture Requirements:
   1. Air-Handling Systems: For control applications of an air-handling system that consists of air-handling unit(s) and VAV terminal units, include a dedicated LAN of controllers serving VAV terminal units connected directly to the controller that is controlling air-handling-system air-handling unit(s). Basically, create a DDC system LAN that aligns with the air-handling system being controlled.
   2. Tier 3 Serial Networks: All control devices on a common serial network shall be configured to a common communication baud rate.

H. Field sensors and control devices shall connect to peer-to-peer, fully programmable B-BC, B-AAC & B-ASC as required to achieve the point monitoring and Sequence of Control as specified herein. All devices are to be monitored by a B-AWS. Final control devices are to be electronic.

I. Each Mechanical System and/or major piece of Mechanical Equipment shall have one (1) dedicated B-BC controller with sufficient I/O capacity such that it shall be connected to ALL field devices and sensors associated with that system and/or piece of equipment. Distributed control of one (1) single piece of major mechanical equipment shall not be performed by multiple controllers.

J. All BAS controllers, sensors and devices shall be UL listed.
   1. All BAS controllers and interface devices must be UL 916 Listed.

1.8 SYSTEM PERFORMANCE

A. Comply with the following performance requirements:
   1. DDC System Speed:
      a. Response Time of Connected I/O:
         1) Update AI point values connected to DDC system every five seconds for use by DDC controllers. Points used globally to also comply with this requirement.
         2) Update BI point values connected to DDC system every five seconds for use by DDC controllers. Points used globally to also comply with this requirement.
         3) AO points connected to DDC system to begin to respond to controller output commands within two seconds. Global commands to also comply with this requirement.
         4) BO point values connected to DDC system to respond to controller output commands within two seconds. Global commands to also comply with this requirement.
      b. Display of Connected I/O:
         1) Update and display analog point COV connected to DDC system every ten seconds for use by operator.
         2) Update and display binary point COV connected to DDC system every ten seconds for use by operator.
         3) Update graphic display refresh within 8 seconds.
         4) Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations shall not exceed graphic refresh rate indicated.

2. Network Bandwidth: Design each network of DDC system to include spare bandwidth with DDC system operating under normal and heavy load conditions indicated. Calculate bandwidth usage and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions. Minimum spare bandwidth as follows:
    a. Tier 1 Networks: 30 percent.
    b. Tier 2 Networks: 30 percent.
    c. Tier 3 Networks: 30 percent.
3. DDC System Data Storage:
    a. Include capability to archive not less than 48 consecutive months of historical data for all I/O points connected to system, including alarms, event histories, transaction logs, trends, and other information indicated.
    b. Local Storage:
        1) Provide server with data storage indicated. Server(s) to use IT industry standard database platforms and be capable of functions described in "DDC Data Access" Paragraph.
4. DDC Data Access:
    a. When logged into the system, operator able to also interact with any DDC controllers connected to DDC system as required for functional operation of DDC system.
    b. Use for application configuration; for archiving, reporting, and trending of data; for operator transaction archiving and reporting; for network information management; for alarm annunciation; and for operator interface tasks and controls application management.
5. Future Expandability:
    a. DDC system size is expandable to an ultimate capacity of at least 1.25 times total I/O points indicated.
    b. Design and install system networks to achieve ultimate capacity with only addition of DDC controllers, I/O, and associated wiring and cable. Design and install initial network infrastructure to support ultimate capacity without having to remove and replace portions of network installation.
    c. Operator interfaces installed initially do not require hardware and software additions and revisions for system when operating at ultimate capacity.
6. Object Scan: Transmit change of state and change of analog values to control units or workstation within six seconds.
7. B-BC, B-AAC, & B-ASC shall be able to execute control loops at a selectable frequency at least 1 time every second. The controller shall scan and update the process value and output generated by this calculation at this same frequency at a minimum.
8. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.
9. Program Execution Frequency: Run capability of applications as often as five seconds but selected consistent with mechanical process under control.
10. Performance: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at least once per second.
11. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
    a. Water Temperature: Plus or minus 0.5 deg F.
    b. Water Flow: Plus or minus 1 percent of full scale.

c. Water Pressure: Plus or minus 2 percent of full scale.
d. Space Temperature: Plus or minus 0.5 deg F.
e. Ducted Air Temperature: Plus or minus 0.5 deg F.
f. Outside Air Temperature: Plus or minus 0.5 deg F.
g. Dew Point Temperature: Plus or minus 3 deg F.
h. Temperature Differential: Plus or minus 0.25 deg F.
i. Relative Humidity: Plus or minus 5 percent.
j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.
k. Airflow (Measuring Stations): Plus or minus 5 percent of full scale.
l. Airflow (Terminal): Plus or minus 10 percent of full scale.
m. Air Pressure (Space): Plus or minus 0.01-inch wg.
n. Air Pressure (Ducts): Plus or minus 0.1-inch wg.
o. Carbon Monoxide: Plus or minus 5 percent of reading.
p. Carbon Dioxide: Plus or minus 50 ppm.
q. Nitrogen Dioxide: Plus or minus 50 ppm.
r. Electrical: Plus or minus 5 percent of reading.

12. Overall combined system repeatability of sensors, controllers and readout devices for a particular application shall be plus or minus 2% of full scale of the operating range. Repeatability of overall combined system of sensor, controller and readout device in a control loop application will be plus or minus 5% of full scale of the operating range.
13. Long-term electronic drift shall not exceed 0.4% per year.
14. All components provided as part of this system shall operate under ambient environmental conditions of 20F to 104F dry bulb and 10% to 90% relative humidity, noncondensing as a minimum. Sensors and control elements shall operate under the ambient environmental temperature, pressure, humidity, and vibration conditions encountered for the installed location. B-OWS equipment (hardware only), such as CRTs and printers, shall, unless designated otherwise, operate properly under ambient environmental conditions of 45F to 90F and a relative humidity of 10% to 90%.
15. Networked components of the system shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80%.
16. Environmental Conditions for Controllers, Gateways, and Routers:
    a. Products to operate without performance degradation under ambient environmental temperature, pressure, and humidity conditions encountered for installed location.
        1) If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure to be internally insulated, electrically heated, cooled, and ventilated as required by product and application.
    b. Protect products with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. House products not available with integral enclosures complying with requirements indicated in protective secondary enclosures. Installed location dictates the following NEMA 250 enclosure requirements:
        1) Outdoors, Protected: Type 3.
        2) Outdoors, Unprotected: Type 4X.
        3) Indoors, Heated with Filtered Ventilation: Type 1.

4) Indoors, Heated with Non-Filtered Ventilation: Type 2.
5) Indoors, Heated and Air-Conditioned: Type 1.
6) Mechanical Equipment Rooms:
a) Chiller and Boiler Rooms: Type 4.
b) Air-Moving Equipment Rooms: Type 2.
7) Localized Areas Exposed to Washdown: Type 4X.
8) Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 3.
9) Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: Type 4.
10) Hazardous Locations: Explosion-proof rating for condition.

17. Environmental Conditions for Instruments and Actuators:
a. Instruments and actuators to operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
1) If instruments and actuators alone cannot comply with requirement, install instruments and actuators in protective enclosures that are isolated and protected from conditions impacting performance. Enclosure is internally insulated, electrically heated, cooled, and ventilated as required by instrument and application.
b. Protect instruments, actuators, and accessories with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. House instruments and actuators not available with integral enclosures complying with requirements indicated in protective secondary enclosures. Installed location is to dictate the following NEMA 250 enclosure requirements:
1) Outdoors, Protected: Type 3.
2) Outdoors, Unprotected: Type 4X.
3) Indoors, Heated with Filtered Ventilation: Type 1.
4) Indoors, Heated with Non-Filtered Ventilation: Type 2.
5) Indoors, Heated and Air-conditioned: Type 1.
6) Mechanical Equipment Rooms:
a) Chiller and Boiler Rooms: Type 4.
b) Air-Moving Equipment Rooms: Type 2.
7) Localized Areas Exposed to Washdown: Type 4X.
8) Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 3.
9) Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: Type 4.
10) Hazardous Locations: Explosion-proof rating for condition.

18. Backup Power Source:
a. Serve DDC system products that control HVAC systems and equipment served by a backup power source also from a backup power source.

19. UPS:
a. DDC system products powered by UPS units are to include the following:
1) Gateways.
2) DDC controllers.

20. Continuity of Operation after Electric Power Interruption:

a. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems are to automatically return equipment and associated controls to operating state occurring immediately before loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

B. Energy Dashboard
1. Provide interactive, educational dashboard using a web application to display real-time energy data and building performance metrics in a common area shown on the drawings. Incorporate Owner branding and coordinate content with the Owner and A/E of record. Provide user interface for content management that allows the Owner to update text and photos. Provide one 48 inches wall-mounted commercial-grade monitor and infrared multi-touch overlay with 3-year warranty. Provide 24/7 content scheduler.

1.9 SEQUENCE OF OPERATIONS

A. See the contract drawings for system sequence of operations for each system to be controlled.

B. Program each DDC controller, third party equipment, etc., to perform the sequences of operation provided on the construction documents. Provide all necessary hardware on each piece of equipment in order for the equipment to perform the specified sequence and to meet the requirements of the point lists where provided.

C. The Contractor shall be responsible for all control wiring connections, auxiliary devices and control wiring diagrams to complete the control system and attain the described sequence of operation.

1.10 ACTION SUBMITTALS

A. Submit in writing and so delineated at the beginning of each submittal, known substitutions and deviations from requirements of Contract Documents. Deviation from Contract Documents must be approved by the Engineer of record prior to submittal.

B. Sequence of Operations, Controls Diagram, BAS architecture, Bill of Materials, Controls Matrix and Points lists shall be a SEPARATE submittal (under separate cover) from all equipment product data associated with the controls system. Documents should be word searchable and utilize bookmarks.

C. Complete BAS Engineering Design Submittal & Drawings shall be prepared pursuant with the following guidelines:
1. Submittal documentation and drawings shall consistently use the same abbreviations, symbols, nomenclature and identifiers. Each control system element shall be assigned a unique identifier pursuant with the Contract Documents.
2. Submittal documentation and drawings shall have at the beginning an Index and Design Drawing Legend.
a. Index shall list all design drawings and elements including the drawing number, sheet number, drawing title, etc.

b. Legend shall show and describe all symbols, abbreviations and acronyms used on the Design Drawings.

D. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
1. DDC System Hardware: Bill of materials of equipment indicating quantity, manufacturer, and model number. Include technical data for operator workstation equipment, interface equipment, control units, transducers/transmitters, sensors, actuators, valves, relays/switches, control panels, and operator interface equipment.
2. Control System Software: Include technical data for operating system software, operator interface, color graphics, and other third-party applications.
3. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.

E. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
1. Bill of materials of equipment indicating quantity, manufacturer, and model number.
2. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
3. Wiring Diagrams: Power, signal, and control wiring.
4. Plan Drawings indicating the following:
   a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork, and piping.
   b. Room names and numbers with coordinated placement to avoid interference with control products indicated.
   c. Each desktop workstation network port, server, gateway, router, DDC controller, control panel instrument connecting to DDC controller, and damper and valve connecting to DDC controller, if included in Project.
   d. Exact placement of products in rooms, ducts, and piping to reflect proposed installed condition.
   e. Network communication cable and raceway routing.
   f. Information, drawn to scale.
   g. Proposed routing of wiring, cabling, conduit, and tubing; coordinated with building services for review before installation.
5. Riser diagram of the building communication network shall outline execution and details of all network cabling, BAS & Network Hardware including the following:
   a. All BAS/DDC Hardware with controller number, unique identifier/tag, location, equipment and service.
   b. All Network Hardware with unique identifier, location and service.
   c. Network cabling configuration and execution specification.
   d. Location of all cabling termination points and End of Line (EOL) terminators.
   e. Location of all network interface jacks.

f. For each network, indicate communication protocol, speed, and physical means of interconnecting network devices, such as copper cable type, or optical fiber cable type. Indicate raceway type and size for each.
g. A separate riser diagram shall be provided for each network segment.

6. Details of control panel faces, including controls, instruments, and labeling.

7. Control panel drawings indicating the following:
   a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
   b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates, and allocated spare space.
   c. Front, rear, and side elevations and nameplate legend.
   d. Unique drawing for each panel.
8. A schedule of all BAS network devices including the unique equipment identifier/tag, description, IP address, MAC address, control panel name, and installation location.
9. A schedule of all control valves including the unique equipment identifier/tag, valve size, dimensions and installation/maintenance clearance, model number (including pattern and connections), close-off rating, flow, CV, pressure drop, pressure rating and location. The valve schedule shall also contain actuator selection data supported by calculations of the force required to move, close and seal the valve at design conditions.
10. A schedule of all control dampers. This shall include the unique equipment identifier, unique damper identifier/tag, damper size, pressure drop, blade configuration, orientation and axis of frame, blade rotation, location and selection criteria of actuators, nominal and actual sizes, and manufacturer and model number. The Damper Schedule shall include the AMCA 500-D maximum leakage rate at the operating static-pressure differential.

11. Sequence of Operation shall be submitted for every piece of equipment being controlled by and/or associated with the BAS. No operational deviation from specified Sequences of Operation as outlined in Contract Documents shall be permitted without prior written approval. Sequences of Operation shall include and conform to the following:
    a. Refer to equipment and control devices by their specific unique identifiers/tags pursuant with the Contract Documents and BAS Submittal package.
    b. Clearly represent actual Application Programming methodology and functional control operation. Do not merely provide a copy of Contract Document specified Sequence of Control.
    c. Include description of functional system operation under normal and failure conditions.
12. DDC System Hardware:
    a. Wiring diagrams for control units with termination numbers.
    b. Schematic diagrams and floor plans for field sensors and control hardware.
    c. Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between operator workstation and control unit locations.

13. Control System Software:
    a. Cross-referenced listing of software to be loaded on each operator workstation, server, and DDC controller.
    b. Description and technical data of all software provided and cross-referenced to products in which software will be installed.
    c. Operating system software, operator interface and programming software, color graphic software, DDC controller software, maintenance management software, and third-party software.
    d. Include a flow diagram and an outline of each subroutine that indicates each program variable name and units of measure.
    e. Listing and description of each engineering equation used with reference source.
    f. Listing and description of each constant used in engineering equations and a reference source to prove origin of each constant.
    g. Description of operator interface to alphanumeric and graphic programming.
    h. Description of each network communication protocol.
    i. Description of system database, including all data included in database, database capacity, and limitations to expand database.
    j. Description of each application program and device drivers to be generated, including specific information on data acquisition and control strategies showing their relationship to system timing, speed, processing burden, and system throughout.
    k. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.
14. Color graphics indicating the following:
    a. Itemized list of color graphic displays to be provided.
    b. For each display screen to be provided, a true color copy showing layout of pictures, graphics, and data displayed.
    c. Intended operator access between related hierarchical display screens.
15. Controlled Systems:
    a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
    b. I/O listed in table format showing point name, point type, type of device, manufacturer, model number, trend configuration, and cross-reference to product data sheet number.
    c. A graphic showing location of control I/O in proper relationship to HVAC system.
    d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
    e. Unique identification of each I/O that to be consistently used between different drawings showing same point.
    f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays, and interface to DDC controllers.
    g. Narrative sequence of operation.
    h. Graphic sequence of operation, showing all inputs and output logical blocks.

1.11 INFORMATIONAL SUBMITTALS

A. Data Communications Protocol Certificates: Certify that each proposed DDC system component complies with ASHRAE 135. Provide BACnet protocol information conformance statement (PICS) for each control device.

B. Qualification Data: For Installer and manufacturer.

C. Software Upgrade Kit: For Owner to use in modifying software to suit future systems revisions or monitoring and control revisions.

D. Field quality-control test reports.

1.12 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For HVAC instrumentation and control system to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
   1. Operator's Manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing set points and variables.
   2.
   3. Programming Manual including:
      a. Documentation of all project specific Application and DDC programs.
      b. All necessary system Administrator-Level passwords and/or required access credentials.
      c. Information required for programming BAS.
      d. Complete Final Point Schedule including all hardware and software data points and documentation of calibration and configuration values for all Inputs, Outputs, Variables and PID Loops at the conclusion of systems commissioning and functional testing.
      e. Routine preventative maintenance procedures, corrective diagnostic troubleshooting procedures and calibration processes.
      f. Final Bill of Material with all installed parts, manufacturers, manufacturers' part numbers and ordering information.
      g. A schedule of recommended spare parts with part numbers and supplier.
   4. Complete system database as functional at the conclusion of systems commissioning and functional testing including all graphics and images used by and/or created for BAS on electronic format as accepted by Owner.
   5. Maintenance instructions and lists of recommended spare parts for each type of control device.
   6. Interconnection wiring diagrams with identified and numbered system components and devices.
   7. Keyboard illustrations and step-by-step procedures indexed for each operator function.
   8. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
   9. Calibration records and list of set points. Including calibrated trip points for differential pressure switches.

10. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
11. Names, addresses, email addresses, and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
12. Owner training materials.

B. Software and Firmware Operational Documentation: Include the following:
1. Software operating and upgrade manuals.
2. Program Software Backup: On a magnetic media or compact disc, complete with data files.
3. Device address list.
4. Printout of software application and graphic screens for all major equipment or systems, such as chilled water plant including all components, typical air handling units, etc.
5. Software license required by and installed for DDC workstations and control systems.

C. Project Record Documents. Upon completion of installation and systems commissioning submit record documents for review. As-Built Project Record Documents should include:
1. Project Record Application Engineering Drawings shall include all BAS System Engineering Design Submittal with Drawings updated to reflect actual field conditions, architecture and execution.

1.13 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish **~~a recommended list of~~ (Add. B)** materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Two Relays each type.
2. Two Space sensors each type.
3. One Duct sensor each type.
4. One actuator each type.
5. One duct pressure DPT.
6. One transformer each type.
7. One controller each type.
8. **Five vav controllers (Add. B)**
9. One Supervisory controller each type.

1.14 QUALITY ASSURANCE

A. DDC System Manufacturer Qualifications:
1. Nationally recognized manufacturer of DDC systems and products.
2. DDC systems with similar requirements to those indicated for a continuous period of five years within time of bid.
3. DDC systems and products that have been successfully tested and in use on at least five past projects.
4. Having complete published catalog literature, installation, operation, and maintenance manuals for all products intended for use.
5. Having full-time in-house employees for the following:
   a. Product research and development.
   b. Product and application engineering.

c. Product manufacturing, testing, and quality control.
d. Technical support for DDC system installation training, commissioning, and troubleshooting of installations.
e. Owner operator training.

B. DDC System Provider Qualifications:
1. Authorized representative of, and trained by, DDC system manufacturer.
2. In-place facility located within 50 miles of Project.
3. Demonstrate past experience with installation of DDC system products being installed for period within five consecutive years before time of bid.
4. Demonstrate past experience on five projects of similar complexity, scope, and value.
5. Demonstrate past experience of each person assigned to Project.
6. Staffing resources of competent and experienced full-time employees that are assigned to execute work according to schedule.
7. Service and maintenance staff assigned to support Project during warranty period.
8. Product parts inventory to support ongoing DDC system operation for a period of not less than five years after Substantial Completion.
9. DDC system manufacturer's backing to take over execution of the Work if necessary to comply with requirements indicated. Include Project-specific written letter, signed by manufacturer's corporate officer, if requested.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

D. Comply with ASHRAE 135 for DDC system components.

1.15 EXTENDED WARRANTIES

A. Warrant all DDC controllers to be free of defect in material and workmanship under normal operation and expected service as published by the manufacturer in the unit's performance specifications for a period of two (2) years at a minimum.

B. Warrant all carbon dioxide (CO2) sensing elements to be free of defect in material and workmanship under normal operation and expected service as published by the manufacturer in the unit's performance specifications for a period of three (3) years at a minimum.

C. Warrant all relative humidity (RH) sensing elements to be free of defect in material and workmanship under normal operation and expected service as published by the manufacturer in the unit's performance specifications for a period of three (3) years at a minimum.

D. Warrant all other components of the BAS and installation to be free of defects in workmanship and material under normal expected service and use for a period of two (2) years from the date of final acceptance of the BAS by the Owner.

E. During the warranty period, provide all labor and materials required to repair or to replace all items or components that fail due to defects in workmanship or manufacture at no charge or reduction in service to the Owner.

F. Except in the event of property loss or damage, warranty service shall be provided during regular working hours Monday through Friday at no charge unless otherwise explicitly outlined in the Contract Documents. Warranty work outside these periods and associated charges shall be coordinated with Owner.

1.16 DELIVERY, STORAGE, AND HANDLING

A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.

B. System Software: Update to latest version of software at Project completion.

1.17 COORDINATION

A. Coordinate location of all thermostats, humidistats, and other exposed control sensors with plans and room details before installation.

B. Coordinate with all related systems, subcontractors and the associated manufacturers responsible for the system to determine the points that are to be mapped from the third-party system to the BAS. At a minimum, provide mapping, alarm configuration, and graphic creation for each system.

C. Coordinate systems outside of Divisions 23 that have been included as a part of the overall BMS system. Achieve compatibility with systems and equipment that interfaces with the BMS systems. Such systems may include:
   1. Plumbing Metering.
   2. Plumbing Equipment provided under Division 22.
   3. Intrusion Detection.
   4. Access Control and Security Systems.
   5. Clock Systems.
   6. PLC Electronic Detention Monitoring and Control Systems.
   7. Addressable-fixture Lighting Controls.
   8. Digital, Addressable Fire Alarm System.
   9. Electrical Power Monitoring and Control.
   10. Panelboards.
   11. Motor-Control Centers.
   12. Emergency Power Equipment.
   13. Conditioned electrical branch circuits for BMS devices.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Automated Logic Corporation.

B. Control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, accessories, and software connected to distributed controllers operating in multiuser, multitasking environment on token-passing network and programmed to control mechanical systems. An operator workstation permits interface with the network via dynamic color graphics with each mechanical system, building floor plan, and control device depicted by point-and-click graphics.

C. Incorporate other monitored or controlled systems identified in paragraph 1.17.C above.

2.2 BACNET ADVANCED OPERATORS WORKSTATION PLATFORM (B-AWS)

A. The BACnet Advanced Operator Workstation Platform (B-AWS) provides complete configuration, monitoring, modification and operation of the entire DDC System by advanced building operators and technicians.

B. Provide as specified herein complete all associated Operating System, Operators Workstation Application Software and Third-Party Software Applications preloaded and configured.

C. BACnet Advanced Operator Workstation Platform (B-AWS) shall reside on the Enterprise Level Communication Network (ELCN) or the Building Level Communication Network (BLCN) using the BACnet/IP data link as specified in ANSI/ASHRAE Standard 135.

1. Provide one PC-based microcomputer(s) with minimum configuration as follows:
   a. Motherboard: 8 integrated USB 3.0 or higher, Gigabit Ethernet (10/100/1000), integrated audio, and BIOS with TPM 2.0 and secure boot support.
   b. Processor: Intel Core i7 (11th Gen or newer), 3.3 GHz base frequency or higher.
   c. SD Random-Access Memory: 32 GB RAM or higher.
   d. Graphics: Integrated graphics (e.g., Intel Iris Xe or equivalent).
   e. Monitor: 21.5” or larger Full HD (1920x1080) LCD.
   f. Keyboard: Full-size QWERTY keyboard.
   g. Hard-Disk Drive: 8 TB SSD.
   h. DVD Read/Write Drive: Internal or external USB DVD Read/Write Drive (if required).
   i. Mouse: Optical USB mouse.
   j. Uninterruptible Power Supply: 2 kVa.
   k. Operating System: Microsoft Windows 11 Professional.
2. Network Protocol Compliance: Workstation shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
   Printer: Color, ink-jet type as follows:
   a. Print Head: Minimum 4800 x 1200 dpi optimized color resolution.
   b. Paper Handling: Minimum of 100 sheets.
   c. Print Speed: Minimum of 17 ppm in black and 12 ppm in color.
3. Application Software:
   a. I/O capability from operator station.
   b. System security for each operator via software password and access levels.

c. Automatic system diagnostics; monitor system and report failures.
d. Database creation and support.
e. Automatic and manual database save and restore.
f. Dynamic color graphic displays with up to 50 screen displays at once.
g. Custom graphics generation and graphics library of HVAC equipment and symbols.
h. Alarm processing, messages, and reactions.
i. Trend logs retrievable in spreadsheets and database programs.
j. Alarm and event processing.
k. Object and property status and control.
l. Automatic restart of field equipment on restoration of power.
m. Data collection, reports, and logs. Include standard reports for the following:
   1) Current values of all objects.
   2) Current alarm summary.
   3) Disabled objects.
   4) Alarm lockout objects.
   5) Logs.
n. Custom report development.
o. Utility and weather reports.
p. Workstation application editors for controllers and schedules.
q. Maintenance management.

4. Custom Application Software:
   a. English language oriented.
   b. Full-screen character editor/programming environment.
   c. Allow development of independently executing program modules with debugging/simulation capability.
   d. Support conditional statements.
   e. Support floating-point arithmetic with mathematic functions.
   f. Contains predefined time variables.

D. Portable BACnet Advanced Operators Workstation (Portable B-AWS): Provide one portable notebook-style, PC-based microcomputer terminal capable of accessing system data by connecting to system network with minimum configuration as follows:
   1. System: Integrated USB 3.0 or USB-C, Gigabit Ethernet (10/100/1000), integrated audio, and BIOS with TPM 2.0 and secure boot support.
   2. Processor: Intel Core i5 (11th Gen or newer), 2.4 GHz base frequency or higher.
   3. SD Random-Access Memory: 16 GB RAM or higher.
   4. Graphics: Integrated graphics (e.g., Intel Iris Xe or equivalent).
   5. Monitor: 15.6” Full HD (1920x1080) IPS LCD.
   6. Keyboard: Full-size QWERTY keyboard with touchpad.
   7. Hard-Disk Drive: 2 TB SSD.
   8. Pointing Device: Integrated touchpad or equivalent.
   9. Operating System: Microsoft Windows 11 Professional.
   10. DVD Read/Write Drive: External USB DVD Read/Write Drive (if required).

E. Communications and Protocols
   1. B-AWS information access for the control system shall utilize the BACnet protocol only for communication to B-BCs, B-AACs, B-ASCs and all other BAS DDC controllers.

2. B-AWS shall reside on the same LAN as B-BCs. B-AWS shall as a minimum support point-to-point (PTP) and BACnet/IP physical/data link layer protocols.
3. The B-AWS specified here may, at the Owner's option, be located remote from the BACnet internetwork. Other than the difference in B-AWS communication speed, the system shall be capable of remote operation via BACnet LAN types with no degradation in application performance.
4. B-AWS Operating System (OS) Software shall be consistent on all B-AWS hardware platforms provided.
5. B-AWS Application Software shall be provided and licensed to Owner. Provide latest versions of software available.

2.3 CONTROL SYSTEM ADVANCED OPERATORS WORKSTATION (B-AWS) APPLICATION SOFTWARE

A. BACnet Advanced Operator Workstation Platform (B-AWS) software shall comply with the minimum requirements of ANSI/ASHRAE Standard 135 Annex L for a B-AWS and shall be certified and listed by the BACnet Testing Laboratories (BTL) as a B-OWS. BTL product listings are available from BACnet international.

B. System Configuration
1. The workstation shall provide a complete engineering tool for the configuration of the system. This shall allow for future system changes under proper password protection including dynamic creation, deletion and modification of all configuration parameters, programs, graphics, trend logs, alarms, schedules and every BACnet object used in the installed system.

C. Security
1. Each operator shall be required to log on to the system with a unique username and password in order to view, edit, add or delete data.

D. Operators will be able to perform only those commands available for their respective passwords.
1. System security permissions shall be multi layered and defined for each individual operator to restrict/permit day-to-day operations and system configuration.
   a. A minimum of 10 levels of access shall be supported with a configurable matrix of operator actions allowed for each access level, broken down into at least 200 possible operator actions.
   b. A minimum of 50 passwords shall be supported at each B-OWS.
2. An administrator-level operator shall have the ability to configure credentials for all other operators.
3. User-definable, automatic log-off timers of from 1 to 60 minutes shall be provided to prevent operators from inadvertently leaving B-AWS in an unsupervised logged-in state.
4. Security data shall be stored in an encrypted format.

E. Alarming and Event Notification
1. B-AWS shall utilize BACnet Alarm Events and Protocol Implementation Conformance Statement (PICS) shall support at a minimum the following BACnet Interoperability Building Blocks (BIBBs):
   a. Alarm and Event - Acknowledge-A (AE-ACK-A)
   b. Alarm and Event - Notification-A (AE-N-A)

c. Alarm and Event - Alarm Summary View-A (AE-AS-A)
d. Alarm and Event - View and Modify-A (AE-VM-A)
e. Alarm and Event - View Notifications-A (AE-VN-A)

2. The workstation shall display and log alarms and events from any BACnet object in the system and shall support operator configuration of the alarm limits, differentials, states and reactions for each object in the system.
3. There shall be 4 levels of alarms:
   a. Level 1: Critical/Life Safety
   b. Level 2: Critical Equipment Message
   c. Level 3: Urgent Message
   d. Level 4: Normal Message
4. B-AWS terminal shall provide audible, visual, and printed means of alarm and event notification.
5. System shall provide log of notification messages. Complete Alarm log of all system and operator transactions shall be archived to the hard disk of the system B-AWS.
6. Alarm messages shall be in user-definable text (English) and shall be entered either at the B-AWS terminal or via remote communication.
7. An alarm summary shall be available to show all alarms whether including but not limited to whether or not they have been acknowledged.
8. System shall provide ability to prioritize and differentiate communications for at least 20 different levels of alarms.
9. Alarm messages shall be fully customizable in size, content, behavior and sound.
10. The operator shall be able to view all system alarms from any location in the internetwork. With the proper credentials, an operator shall be able to acknowledge and clear alarms. Alarm and Event Log shall be configurable per workstation and shall display at a minimum alarm time, received time, state, notification class, priority, message, source, time acknowledged, acknowledged by user and action.

F. Weekly Annual and Special Event Scheduling
1. B-AWS Software shall utilize BACnet Schedules and PICS shall support at a minimum the following BIBBs:
   a. Scheduling - Advanced View and Modify-A (SCH-AVM-A)
2. Provide ability to view and modify the schedule for the calendar week and up to 255 special events in a graphical format. Each calendar day and special event shall provide at least ten time/value entries per day.
3. Provide the ability for the operator to select scheduling for either binary, analog, or multi-state object values.
4. Provide the ability for the operator to designate days, date ranges, or repeating date patterns as exception schedules.
5. Provide the capability for the operator to define special or holiday schedules and to link the BACnet schedule to a BACnet calendar, thereby over-riding weekly schedule programming on holidays defined in the BACnet calendar.
6. There shall be a provision with proper password access to manually override each schedule.
7. Provide the capability to designate any exception schedule to be "Executed Once " then automatically cleared.

8. Provide the ability to name each exception schedule with a user defined term to describe each special event.
9. The schedule objects shall reside in each individual device. Workstation or server-based scheduling shall not be acceptable.

G. Trend Log Graphing
1. The B-AWS shall support both the BACnet Trend Log and the BACnet Trend Log Multiple standard objects for defining custom trend logs for any object in the system. This definition shall include interval, length, start time and end time.
   a. The trend data shall be sampled and stored in each individual BACnet device where the object is stored. The workstation or another field level integration platform shall not be required for storage of custom trend logs.
   b. All long-term data archival to hard-disk shall be performed by a BTL-Listed BACnet device dedicated for this service.
2. PICS shall support at a minimum the following BIBBs:
   a. Trending - View-A (T-V-A)
3. All data points (both hardware and software) system-wide shall be assignable to a historical trending program by gathering configurable historical samples of object data stored in the local controller (B-BC, B-AAC, B-ASC).
4. All trend log information shall be displayable in text and graphic format. All information shall be able to be printed in black & white and color and exported directly to a Microsoft Excel Spreadsheet.
5. The B-AWS shall perform the following at a minimum:
   a. Be capable of automatically retrieving any trend-log from any device on the network without user-intervention.
   b. Manage connection to internetwork automatically based upon configurable data acquisition thresholds, retrieving data only when necessary, rather than streaming data.
   c. Shall operate as a Microsoft Windows service.
   d. Be capable of exporting data directly to Microsoft Excel.
   e. Not require a separate viewer but shall seamlessly present all archived data together with real-time data stored in device using the standard B-AWS Trend Log Viewer.

H. Runtime Log Information
1. B-OWS Software shall be capable of displaying Runtime and On/Off Cycle data of all Binary data points (both hardware and software) system-wide.
2. Runtime data shall be sampled and stored in each individual BACnet device where the object is stored using standard BACnet objects and published properties. The workstation shall not be required for storage of custom runtime logs.
3. At a minimum, the Runtime data shall include:
   a. Total accumulated active time.
   b. Total accumulated active transitions and active transitions for the current day.
   c. Timestamp and duration for each change of state for the last 100 transitions.

I. System Configuration, Set-Up and Definition

1. Device and network status shall be displayed for any device on the BACnet internetwork. At a minimum the following Device Management BIBBs shall be supported:
   a. Device Management - Automatic Device Mapping-A (DM-ADM-A).
   b. Device Management - Automatic Network Mapping-A (DM-ANM-A).
2. All control strategies and energy management routines shall be stored in the controller and shall allow modification and additions by the operator using the B-AWS software. No strategies or routines shall be stored on the B-AWS platform.
3. B-AWS Software shall have the capability to back-up and restore the programming and database of any BACnet device on the BACnet internetwork. The B-AWS BTL listing shall support the Device Management - Backup and Restore-A (DM-BR-A) BIBB.
4. Provide a context sensitive, on-line help system to assist the operator in operation and editing of the system.

J. Graphical User Interface (GUI)
1. B-AWS Software shall support at a minimum BMP, GIF, TIF, JPG, EMF, PNG, SWF and DIB graphic file formats and allow for the use of custom Flash animation objects and URL hyperlinks in every GUI.
2. B-AWS Software shall provide a color graphics package to allow the user to generate custom dynamic graphics for graphical representation of system design and system parameters. Graphic images may reside on the B-AWS or server; however, all dynamic data and attributes must reside in the controller.
   a. A listed set of symbols and graphic slides shall be available to allow operators to select from the graphics table to assist in graphic generation.
   b. All color graphic displays shall be dynamic with current point data automatically updated from the BACnet internetwork to the B-AWS workstation without operator intervention.
   c. The operator shall be able to manually adjust all data point values (hardware or software) in the system, adjust values of control loops, and command points to local mode or release points to automatic mode.
   d. The windowing environment of the B-AWS shall allow the user to simultaneously view several graphics at the same time to analyze total building operation, and/or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.
   e. Pre-packaged animations for display of fans, pumps, dampers, etc., and shall allow custom user-created .swf and .gif animations to be used to display objects on graphic displays.

K. Programming Software:
1. Include programming software to execute sequences of operation indicated.
2. Include programming routines in simple and easy to follow logic with detailed text comments describing what the logic does and how it corresponds to sequence of operation.
3. Programming Software: Any of the following:
   a. Graphic-based programming is the easiest method of programming options indicated and best suited for operators with limited programming experience. Not all DDC system manufacturers offer graphic-based programming. Consult manufacturers.

1) Graphic Based: Use a library of function blocks made from preprogrammed code designed for DDC control systems.
2) Assemble function blocks with interconnection lines that represent to control sequence in a flowchart.

b. Make programming tools viewable in real time to show present values and logical results of each function block.
c. Menu Based: Done by entering parameters, definitions, conditions, requirements, and constraints.
d. Line by Line and Text Based: Programming is to declare variable types such as local, global, real, integer, and so on, at the beginning of the program. Use descriptive comments frequently to describe programming code.

4. Include means for detecting programming errors and testing software control strategies with a simulation tool before implementing in actual control. Simulation tool may be inherent with programming software or as a separate product.

L. The BAS shall be provided with fully automatic diagnostic procedures for verification of internetwork communication. In the event of communications failure, the system shall automatically Alarm the condition. B-AWS Software shall be capable of remote annunciation to printer, pager and e-mail.

M. Control Summaries, Reports and Logging:
1. The system shall provide self-documentation reporting to summarize control strategies for any point or any user selected group of points within the Control System.
2. The B-AWS reporting package shall allow the user to configure the point information display in custom format.
3. The B-AWS shall enable operator to perform Wild Card data point sorting and searches.
4. The B-AWS shall perform automated network back-up of runtime databases in all devices on the BACnet network according to operator configurable schedule and storage directory structure.
5. Standard Reports: Provide standard DDC system reports with operator ability to customize reports later.
a. All I/O: With current status and values.
b. Alarm: All current alarms, except those in alarm lockout.
c. Disabled I/O: All I/O points that are disabled.
d. Alarm Lockout I/O: All I/O points in alarm lockout, whether manual or automatic.
e. Alarm Lockout I/O in Alarm: All I/O in alarm lockout that are currently in alarm.
f. Logs:
1) Alarm history.
2) System messages.
3) System events.
4) Trends.
6. Custom Reports: Operator able to easily define and prepare any system data into a daily, weekly, monthly, annual, or other historical report. Reports to include a title with time and date stamp.

2.4 BUILDING LEVEL CONTROLLERS (B-BC)

A. All building level controllers shall comply with the minimum requirements of ANSI/ASHRAE Standard 135 Annex L for a BACnet Building Controllers (B-BCs) and shall be certified and listed by the BACnet esting Laboratories (BTL) as a B-BC.

B. Furnish B-BC(s) as necessary to control large point count major mechanical equipment, and execution of BAS global strategies, and as noted in the execution portion of this specification.
   1. Each Mechanical System and/or major piece of Mechanical Equipment (e.g., Chilled Water, Heating Water, Large AHU, etc.) shall have one (1) dedicated DDC controller with sufficient I/O capacity such that it shall be connected to ALL field devices and sensors associated with that system and/or piece of equipment. Distributed control of one (1) single piece of major mechanical equipment shall not be performed by multiple controllers.
   2. Each B-BC shall support local hardware Inputs and Outputs (I/O) by the use of on-board I/O and/or I/O expansion modules.

C. Building level controllers shall reside on the Tier 2 or Tier 3 using the BACnet/IP, BACnet/Ethernet or MS/TP data links as specified in ANSI/ASHRAE Standard 135.

D. B-BC shall be capable of locally executing global strategies for the BAS based on information from any object in the internetwork. Control Systems that require a higher-level host processor for update, time stamps, global point data, COS transfer, on-line control instruction, or communications control between B-BC panels shall not be acceptable.

E. BAS shall communicate with all B-AWS, B-BC, B-AAC & B-ASC on a peer-to-peer basis and shall provide real-time clock functions for scheduling and network-wide time synchronization.

F. B-BC shall have sufficient memory to support its operating system, database, and programming requirements. Battery/capacitor shall retain static RAM memory and clock functions for a minimum of 72 hours.
   1. B-BC operating system, field database, and application programs shall reside in EEPROM.
   2. B-BC run-time field database and application programs shall reside in battery backed-up on-board memory of EEPROM.

G. B-BC shall comply with the following Hardware Configuration:
   1. B-BC shall have integral power switch. If the device manufacturer provides no on-board switch, then the System Contractor shall provide a separate dedicated transformer and switch within each enclosure for each controller present.
   2. B-BC shall provide diagnostic LEDs for power, communications and processor status. The B-BC shall continually check the status of its processor and memory circuits.
   3. Controller wiring terminals shall be removable terminal strips for ease of installation and service replacement.
   4. All hardware inputs shall be Universal (i.e., binary or analog) configured on hardware and/or in software.
      a. Inputs shall accept dry-contact, thermistor, 4-20 mA, 0-5VDC, and 0-10VDC.

b. Pulse accumulation shall accommodate a maximum frequency of 40Hz.
c. Inputs shall have a minimum 10 Bit A/D conversion resolution.
d. 24VAC over-voltage protection
e. Status LED indicators for each input

5. All hardware outputs shall be Universal and configured on hardware and/or in software.
   a. Outputs shall provide configurable modulating voltage signal to industry standard 0-5VDC/0-10VDC, and modulating 4-20 mA analog control devices and relays.
   b. Outputs shall be capable of sourcing 75mA at 12VDC.
   c. Outputs shall have a minimum 8 Bit D/A conversion resolution.
   d. 24VAC over-voltage and short protection

H. B-BC shall interact with the Control System Application Software in compliance with the following:
1. Database programming, configuration and modification shall be accomplished through the B-AWS online with the B-BC. The complete database and application program shall reside in the B-BC. The System Contractor shall configure the software to attain the proper sequence of control and to accomplish all other control system functions indicated in the Contract Documents. Provide a copy of all programming on disc to the Owner.
2. The B-BC shall function in a real-time, multi-tasking networked operating environment; able to display database values, programs, and control loops in real-time while functional and online using the B-AWS. The user shall be able to add, delete, or modify objects on-line as required without taking the B-BC offline. The programming shall provide all the necessary mathematics, logic, utility and control functions necessary to execute the specified sequence of control.
3. All required application programming shall be resident in the B-BC, B-AAC & B-ASC, and not in the B-AWS.
4. B-BC shall manage system-wide alarms by performing distributed, independent alarm analysis and filtering. At no time shall the B-BC panel's ability to report alarms be affected by either operator activity at a B-AWS or local I/O device, or communications with other B-BC on the network.
   a. B-BCs shall have capability to broadcast alarm conditions automatically across the Tier 1 or Tier 2 Network. Alarm Event notifications shall be sent to off-site computer or serial printer. A minimum of one B-BC per site shall be capable of sending SMTP email messages to an email server for configured alarm conditions.
   b. Active Alarm Events log shall be stored on the B-BC and may be viewed locally or remotely.
   c. All alarm or point change reports shall include the point's English language description, and the time and date of occurrence.
   d. The user shall be able to define the specific system reaction for each point alarm and shall be able to customize reaction and filtering to minimize nuisance reporting. Each B-BC panel shall automatically inhibit the reporting of selected alarms during the standby power modes of operation, loss of power, fire alarm mode, and normal system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point.

e. Alarm reports, messages, and files can be directed to a user-defined list of operator devices, or PCs used for archiving alarm information.

5. B-BC shall perform and manage historical data collection. Minimum sampling time shall be configurable with a minimum sample rate of once per second.
   a. B-BC panels shall store point history files for all analog and binary inputs and outputs.
   b. Measured and calculated analog and binary data shall also be assignable to user-definable trends.
   c. Trend data shall be stored at the stand-alone B-BC panels and uploaded to hard disk storage automatically at preconfigured intervals when archival is desired. B-BC shall be equipped with enough storage for a minimum of 24 hours of trend data.
6. Stand-alone B-BC panels shall automatically accumulate and store runtime hours for binary input and output points.
7. B-BC panels shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points.
8. B-BC panels shall have the ability to count and/or execute events on a daily, weekly, or monthly basis.

I. Communication and Protocols
1. The B-BC shall continuously scan the BACnet network and maintain a current database of field data in on board battery/capacitor backed RAM or EEPROM, including alarms, passwords, binding tables, device status, etc. The B-BC shall communicate with BACnet devices on the Tier 3 network using the BACnet physical data link MS/TP at a baud rate of no less than 76.8 Kbps where not limited by third party BACnet devices such as variable frequency drives, utility meters, etc.
2. The B-BC shall provide a communications port for connection of the Portable Operators Terminal using Point-to-Point BACnet physical data link layer protocol or a connection to the network using BACnet/IP.
3. B-BC shall support and be capable of monitoring and controlling a network of communicating remote space sensors. These networked sensors shall occupy input/output hardware points in the B-BC.
4. B-BC shall support at a minimum of two (2) distinct dedicated BACnet/IP (B/IP) data link networks using TCP/IP and one (1) BACnet/Ethernet data link network simultaneously.
5. Building level controllers shall support the following communications requirements at a minimum:
   a. Client and Server BACnet Subscribe Change of Value (COV) Service.
   b. Client and Server BACnet Read Property Multiple (RPM) Service.
   c. BACnet transmit and receive frame segmentation.
   d. Post-installation, field-configurable maximum information frames, APDU frame timeout, APDU segment timeout and APDU retries.
6. Building level controllers shall support SMTP and provide stand-alone remote annunciation of alarms via e-mail without additional hardware, B-AWS or web-server.

2.5 ADVANCED APPLICATION CONTROLLERS (B-AAC)

A. B-AAC shall comply with all aforementioned BAS System Requirements and shall comply with or exceed the BACnet profile for Advanced Application Controllers (B-AAC).

B. Furnish one dedicated B-AAC(s) for each small or medium sized mechanical system. Additionally, furnish one dedicated B-AAC for each Terminal Unit Mechanical Device on the project. Those include Variable Air Volume (VAV) Air Terminal Units (ATU), Serial and Parallel Fan-Powered (FP) VAV ATUs, Unit Heaters (UH), Unit Ventilators (UV), Fan Coil Units (FCU) and Individual Fans.

C. Each B-AAC shall acquire, process, and store point input data on a real time basis for internal use and for sharing with other controllers. Each B-AAC shall also maintain and supervise digital and analog output signals to the control devices and have a real-time operating system capable of time-of-day scheduling and other time-based functions.
   1. If the hardware point requirements of any medium-sized system should exceed the I/O configuration of available B-AAC offerings, then a B-BC must be used. Control of one piece of mechanical equipment may not be performed by more than one controller.

D. B-AAC shall provide microprocessor based self-contained stand-alone fully programmable operation of local process control loops. All local level application programs shall be installed on individual controllers in non-volatile memory.

E. Each B-AAC shall be capable of sharing point information with other B-BC, B-AAC, or B-ASC on a peer-to-peer basis via the BACnet Tier 2 or Tier 3 network.

F. Control systems that utilize canned programs or programmable read only memory (PROM) level application programming are not acceptable.

G. Once downloaded, a B-AAC shall not require further communication with the B-AWS except for database changes, operator commands, and requests from the B-AWS for B-AAC data. Programming of B-AACs shall be completely modifiable in the field, over the installed BACnet network.

H. Each B-AAC shall be provided with the ability to prevent unauthorized access to its software program.

I. B-AAC shall have sufficient memory to support its operating system, database, and programming requirements.
   1. B-AAC operating system, field database, and application programs shall reside in EEPROM.

J. B-AAC run-time field database and application programs shall reside in on-board memory or EEPROM.

K. B-AAC shall feature real-time 24-hour clock and 365-day calendar. Battery or capacitor back-up of these functions is required where the B-AAC is installed as a standalone controller.

L. B-AAC shall feature a software configurable audible enunciator which shall be configured to trigger on the occurrence of selected alarms and shall be audible and acknowledgeable either to all users, or only to those users with sufficient password authority.

M. B-AAC shall comply with the following Hardware Configuration:
   1. B-AAC shall provide diagnostic LEDs for power, communications and processor status. The B-AAC shall continually check the status of its processor and memory circuits.
   2. Universal field device hardware inputs shall be provided and configured on hardware and/or in software and comply with the following:
      a. Inputs shall accept dry-contact, thermistor, 4-20 mA, and 0-10VDC
      b. Pulse accumulation shall accommodate a maximum frequency of 100Hz
      c. Inputs shall have a minimum 10 Bit A/D conversion resolution
      d. 24VAC over-voltage protection
   3. Hardware Outputs shall be configured as to be modular in nature.
   4. Universal hardware outputs shall be provided and configured on hardware or in software and comply with the following:
      a. Universal Outputs shall provide configurable modulating voltage signal to industry standard 0-5VDC/ 0-10VDC, and modulating 4-20 mA analog control devices and relays.
      b. Outputs shall be capable of sourcing 75mA at 12VDC and 24VDC.
      c. Outputs shall have a minimum 8 Bit D/A conversion resolution.
      d. 24VAC over-voltage and short protection.

N. B-AAC for VAV ATUs application shall comply with the following additional requirements:
   1. B-AAC shall be provided with integral damper actuator. Actuator shall feature the following at a minimum:
      a. 35 in-lbs of torque.
      b. Brushless DC Operator.
      c. Actual damper position feedback. Drive time or other software calculated damper position shall not be accepted.
      d. Damper End Switch using motor current sense or equivalent for positive feedback of both end stop positions.
      e. Software selectable rotation.
   2. Hardware Outputs shall be configured on hardware and/or in software and comply with the following:
      a. Each TRIAC Output shall source 500 mA current, 24 VAC 0.5 ACA.
   3. Airflow Calibration, Test and Air Balance, etc. shall be performed via dedicated handheld configuration tool connected directly to communication port located at ATU B-ASC sensor. Special proprietary software and/or applications loaded on a computer, tablet or other similar device shall not be acceptable to perform this function.

O. B-AAC for unitary applications shall comply with the following additional requirements:
   1. Controller wiring terminals shall be removable terminal strips for ease of installation and service replacement.
   2. Hardware Outputs shall be configured on hardware and/or in software and comply with the following:
      a. Each TRIAC Output shall source 500 mA current, 24 VAC 0.5 ACA.

P. Control System Application Software:
   1. The B-AAC application software shall be the same as and indistinguishable from the B-BC specified interaction with the Control System Application Software.

2. The controller software shall reside in a real-time, multi-tasking, networking operating environment. Database definition shall be accomplished through B-AWS online with the B-AAC. The complete database and application program shall reside in the B-AAC. Configure the software to attain the proper sequence of control and to accomplish all other control system functions indicated in the Contract Documents.
3. The user shall be able to add, delete, or modify objects on-line as required. Programming shall provide all the necessary mathematics, logic, utility and control functions necessary for proper sequence of control.

Q. Communications and Protocols
1. When connected to the Tier 2 network, the B-AAC shall communicate with field devices and controllers using the BACnet physical IP data link. The B-AAC shall support daisy chain, star, or IP ring topology as required.
2. When connected to the Tier 3 network, the B-AAC shall communicate with field devices and controllers using the BACnet physical data link MS/TP at 76.8 Kbps where not limited by third party devices such as variable frequency drives, utility meters, etc.
3. The B-AAC shall provide a communications port for connection of the Portable Operators Terminal using Point-to-Point BACnet physical data link layer protocol or a connection to the network.
4. B-AAC shall support and be capable of monitoring and controlling a network of a minimum of four (4) communicating remote space sensors. These networked sensors shall not consume input/output hardware points in the B-AAC.

R. B-AAC shall perform and manage historical data collection. Minimum sampling time shall be configurable with a minimum sample rate of once per second.
1. B-AAC panels shall store point history files for all analog and binary inputs and outputs.
2. Measured and calculated analog and binary data shall also be assignable to user-definable trends.
3. Trend data shall be stored at the stand-alone B-AAC panels and uploaded to hard disk storage automatically at preconfigured intervals when archival is desired. B-AAC shall be equipped with enough storage for a minimum of 24 hours of trend data.

S. Stand-alone B-AAC panels shall automatically accumulate and store runtime hours for binary input and output points.

T. B-AAC panels shall automatically sample, calculate and store consumption totals on a daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points.

U. B-AAC panels shall have the ability to count and/or execute events on a daily, weekly, or monthly basis.

V. B-AAC shall support, transmit, and receive of segmented messages.

2.6 APPLICATION SPECIFIC CONTROLLERS (B-ASC)

A. B-ASC shall comply with all aforementioned BAS System Requirements and shall comply with the BACnet profile for Application Specific Controllers (B-ASC).

B. B-ASC shall reside on the Tier 2 or Tier 3 network using the BACnet IP or BACnet MS/TP data link as specified in ANSI/ASHRAE Standard 135 in compliance with the following requirements at a minimum:
   1. Automatically detect the baud of the MS/TP network and then configure the device's communication baud to match that of the MS/TP network.

C. B-ASC shall support the following communications requirements at a minimum:
   1. Client and Server BACnet Subscribe Change of Value (COV) Service.
   2. Client and Server BACnet Read Property Multiple (RPM) Service.
   3. BACnet transmit and receive frame segmentation.
   4. Post-installation, field-configurable maximum information frames, APDU frame timeout, APDU segment timeout and APDU retries.

D. B-ASC controllers are only permitted when they can meet the full requirements of the project’s sequence of operation. Provide one dedicated B-ASC for each Terminal Unit Mechanical Device on the project. Those include Variable Air Volume (VAV) Air Terminal Units (ATU), Serial and Parallel Fan-Powered (FP) VAV ATU's, Unit Heaters (UH), Unit Ventilators (UV), Fan Coil Units (FCU) and Individual Fans.

E. B-ASC shall provide microprocessor based self-contained stand-alone fully programmable operation of local process control loops. All local level application programs shall be installed on individual controllers in non-volatile memory.

F. Each B-ASC shall be capable of sharing point information with other B-BC, B-AAC, or B-ASC on a peer-to-peer basis via the BACnet Tier 2 or Tier 3 network.

G. Control systems that utilize canned programs or programmable read only memory (PROM) level application programming are not acceptable.

H. Once downloaded, a B-ASC shall not require further communication with the B-AWS except for data base changes, operator commands, and requests from the B-AWS for B-ASC data. Programming of B-ASCs shall be completely modifiable in the field, over installed BACnet Internetwork.
   1. Each B-ASC shall be provided with the ability to prevent unauthorized access to its software program.
   2. B-ASC shall have sufficient memory to support its operating system, database, and programming requirements.
   3. B-ASC operating system, field database, and application programs shall reside in EEPROM.
   4. B-ASC run-time field database and application programs shall reside in on-board non-volatile memory or EEPROM.

I. B-ASC shall perform and manage historical data collection. Minimum sampling time shall be configurable with a minimum sample rate of once per second.
   1. B-ASC panels shall store point history files for all analog and binary inputs and outputs.
   2. Measured and calculated analog and binary data shall also be assignable to user-definable trends.
   3. Trend data shall be stored at the stand-alone B-ASC panels and uploaded to hard disk storage automatically at pre-configured intervals when archival is desired. B-ASC shall be equipped with enough storage for a minimum of 24 hours of trend data.

J. Stand-alone B-ASC panels shall automatically accumulate and store runtime hours for binary input and output points.

K. B-ASC panels shall automatically sample, calculate and store consumption totals on a daily, weekly or monthly basis for user-selected analog and binary pulse input-type points.

L. B-ASC panels shall have the ability to count and/or execute events on a daily, weekly, or monthly basis.

M. B-ASC for VAV ATUs application shall comply with the following:
   1. B-ASC shall be provided with integral damper actuator. Actuator shall feature the following at a minimum:
      a. 35 in-lbs of torque.
      b. Brushless DC Operator.
      c. Actual damper position feedback. Drive time or other software calculated damper position shall not be accepted.
      d. Damper End Switch using motor current sense or equivalent for positive feedback of both end stop positions.
      e. Software selectable rotation.
   2. Universal field device hardware inputs shall be provided and configured on hardware and/or in software and comply with the following:
      a. Inputs shall accept dry-contact, thermistor, 4-20 mA, and 0-10VDC.
      b. Pulse accumulation shall accommodate a minimum frequency of 40Hz.
      c. Inputs shall have a minimum 10 Bit A/D conversion resolution.
      d. 24VAC over-voltage protection.
   3. Hardware Outputs shall be configured on hardware and/or in software and comply with the following:
      a. Universal Outputs shall provide configurable modulating voltage signal to industry 0-5VDC / 0-10VDC, and modulating 4-20 mA analog control devices and relays.
      b. Each TRIAC Output shall source 500 mA current, 24 VAC 0.5 ACA.
      c. Universal Output shall be capable of sourcing 75mA at 12VDC.
      d. Outputs shall have a minimum 8 Bit D/A conversion resolution.
      e. 24VAC over-voltage and short protection.
   4. Airflow Calibration, Test and Air Balance, etc. shall be performed via dedicated handheld configuration tool connected directly to communication port located at ATU B-ASC sensor. Special proprietary software and/or applications loaded on a computer, tablet or other similar device shall not be acceptable to perform this function.
   5. B-ASC shall provide diagnostic LEDs for power, communications and processor status. The B-ASC shall continually check the status of its processor and memory circuits.

N. B-ASC for unitary applications shall comply with the following:
   1. B-ASC shall provide diagnostic LEDs for power, communications and processor status. The B-ASC shall continually check the status of its processor and memory circuits.
   2. Controller wiring terminals shall be removable terminal strips for ease of installation and service replacement.

3. Universal field device hardware inputs shall be provided and configured on hardware and/or in software and comply with the following:
   a. Inputs shall accept dry-contact, thermistor, 4-20 mA, and 0-5VDC.
   b. Pulse accumulation shall accommodate a minimum frequency of 40Hz.
   c. Inputs shall have a minimum 10 Bit A/D conversion resolution.
   d. 24VAC over-voltage protection.
4. Hardware Outputs shall be configured on hardware and/or in software and comply with the following:
   a. Universal Outputs shall provide configurable modulating voltage signal to industry 0-5VDC and 0-10VDC analog control devices and relays.
   b. Each TRIAC Output shall source 500 mA current, 24 VAC 0.5 ACA.
   c. Universal Output shall be capable of sourcing 75mA at 12VDC.
   d. Outputs shall have a minimum 8 Bit D/A conversion resolution.
5. 24VAC over-voltage and short protection.

O. Control System Application Software:
1. The B-ASC application software shall be the same as and indistinguishable from the B-BC specified interaction with the Control System Application Software.
2. The controller software shall reside in a real-time, multi-tasking, networking operating environment. Database definition shall be accomplished through the B-AWS online with the B-ASC. The complete database and application program shall reside in the B-ASC. Configure the software to attain the proper sequence of control and to accomplish all other control system functions indicated in the Contract Documents.
3. The user shall be able to add, delete, or modify objects on-line as required. The programming shall provide all the necessary mathematics, logic, utility and control functions necessary for proper sequence of control.

P. Communications and Protocols
1. When connected to the Tier 2 network, the B-ASC shall communicate with field devices and controllers using the BACnet physical IP data link. The B-ASC shall support daisy chain, star, or IP ring topology as required.
2. When connected to the Tier 3 network, The B-ASC shall communicate with field devices and controllers using the BACnet physical data link MS/TP at 76.8 Kbps where not limited by third party devices such as variable frequency drives, utility meters, etc.
3. The B-ASC shall provide a communications port for connection of the Portable Operators Terminal using Point-to-Point BACnet physical data link layer protocol or a connection to the inter-network.
4. B-ASC shall support, transmit, and receive of segmented messages.

Q. I/O Interface: Hardwired inputs and outputs may tie into system through controllers. Protect points so that shorting will cause no damage to controllers.
1. Binary Inputs: Allow monitoring of on-off signals without external power.
2. Pulse Accumulation Inputs: Accept up to 10 pulses per second.
3. Analog Inputs: Allow monitoring of low-voltage (0- to 10-V dc), current (4 to 20 mA), or resistance signals.
4. Binary Outputs: Provide on-off or pulsed low-voltage signal, selectable for normally open or normally closed operation with three-position (on-off-auto) override switches and status lights.

5. Analog Outputs: Provide modulating signal, either low voltage (0- to 10-V dc) or current (4 to 20 mA) with status lights, two-position (auto-manual) switch, and manually adjustable potentiometer.
6. Tri-State Outputs: Provide two coordinated binary outputs for control of three-point, floating-type electronic actuators.
7. Universal I/Os: Provide software selectable binary or analog outputs.

R. Power Supplies: Transformers with Class 2 current-limiting type or overcurrent protection; limit connected loads to 80 percent of rated capacity. DC power supply shall match output current and voltage requirements and be full-wave rectifier type with the following:
1. Output ripple of 5.0 mV maximum peak to peak.
2. Combined 1 percent line and load regulation with 100-mic.sec. response time for 50 percent load changes.
3. Built-in overvoltage and overcurrent protection and be able to withstand 150 percent overload for at least 3 seconds without failure.

2.7 ENCLOSURES AND SUB-PANELS

A. General:
1. House each controller and associated control accessories in enclosure. Enclosure is to serve as a central tie-in point for control devices such as switches, transmitters, transducers, power supplies, and transformers.
2. Do not house more than one controller in a single enclosure.
3. Include enclosure door with key locking mechanism. Key locks alike for all enclosures and include one pair of keys per enclosure.
4. Individual, wall-mounted, single-door enclosures maximum of 36 inches wide and 48 inches high.
5. Freestanding enclosures maximum of 48 inches wide and 72 inches high.
6. Include wall-mounted enclosures with brackets suitable for mounting enclosures to wall or freestanding support stand as indicated.
7. Supply each enclosure with complete set of as-built schematics, tubing, and wiring diagrams and product literature located in pocket on inside of door.
8. Enclosures provided as an integral (pre-packaged) part of another product and/or piece of equipment are acceptable.
9. The enclosures shall be minimum 16-gauge steel or aluminum, totally enclosed on all sides and painted with a baked enamel finish. All enclosures must maintain a minimum separation of 1” from the back wall.
10. Penetrations are permitted on bottom of enclosure only. Do not make conduit penetrations in top or side of enclosure. Each enclosure shall be equipped with a wire gutter below with a minimum of six ¾¾ minimum conduit penetrations into the bottom of the enclosure to accommodate system wiring.

B. Internal Arrangement:
1. Arrange internal layout of enclosure to group and protect pneumatic, electric, and electronic components associated with controller, but not an integral part of controller.
2. Arrange layout to group similar products together.
3. Include a barrier between line-voltage and low-voltage electrical and electronic products.

4. Factory or shop install products, tubing, cabling, and wiring complying with requirements and standards indicated.
5. Terminate field cable and wire using heavy-duty terminal blocks. Provide insulated, modular, feed-through, clamp-style terminal blocks suitable for rail-mounting with end plates and partitions for the termination of all field wiring in control enclosures. Field wiring to equipment with integral terminals and/or unitary equipment (i.e., VAVs ATUs, EFs, &c.) shall not be required to have terminal blocks.
6. Include spare terminals, equal to not less than 10 percent of used terminals.
7. Include spade lugs for stranded cable and wire.
8. Install maximum of two wires on each side of terminal.
9. Include enclosure field electric power supply with toggle-type switch located at entrance inside enclosure to disconnect power.
10. Include enclosure with line-voltage nominal 20 A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with 5 A circuit breaker.
11. Mount products within enclosure on removable internal panel(s).
12. Include products mounted in enclosures with engraved, laminated phenolic nameplates (black letters on a white background). Nameplates are to have at least 1/4-inch- (6-mm-) high lettering.
13. Route tubing cable and wire located inside enclosure within a raceway with continuous removable cover.
14. Label each end of cable, wire, and tubing in enclosure following an approved identification system that extends from field I/O connection and all intermediate connections throughout length to controller connection.
15. Size enclosure internal panel to include at least 15 percent spare area on face of panel.
16. Rail mounted terminal blocks shall be color coded to match the associated conductor colors.
17. Provide each DDC panel with a line filter, surge suppressor, electrical disconnect, control fuse, and control transformer.
18. Protect products from ground fault by providing suitable grounding. Products to not fail due to ground fault condition.

C. Environmental Requirements:
1. Evaluate temperature and humidity requirements of each product to be installed within each enclosure.
2. Calculate enclosure internal operating temperature considering heat dissipation of all products installed within enclosure and ambient effects (solar, conduction, and wind) on enclosure.
3. Where required by application, include temperature-controlled electrical heat to maintain inside of enclosure above minimum operating temperature of product with most stringent requirement.
4. Where required by application, include temperature-controlled ventilation fans with filtered louver(s) to maintain inside of enclosure below maximum operating temperature of product with most stringent requirement.
5. Include temperature-controlled cooling within the enclosure for applications where ventilation fans cannot maintain inside temperature of enclosure below maximum operating temperature of product with most stringent requirement.

6. Where required by application, include humidity-controlled electric dehumidifier or cooling to maintain inside of enclosure below maximum relative humidity of product with most stringent requirement and to prevent surface condensation within enclosure.

2.8 ELECTRONIC POWER DEVICES

A. Control Transformers:
1. Sizing Criteria: Size control transformers for total connected load, plus additional 25 percent of connected load for future spare capacity. Connected load plus future spare capacity shall not exceed 80% of the transformer's rated capacity.
2. Protection: Provide transformers with both primary and secondary fuses. Integral circuit breaker is acceptable in lieu of fuses.
3. Enclosure: House control transformers in NEMA 250 enclosures, type as indicated in "Performance Requirements" Article for application.

B. DC Power Supplies:
1. Description: Linear or switched, regulated power supplies with ac input to one or multiple dc output(s).
2. Include both line and load regulation to ensure stable output.
3. To protect both power supply and load, include power supply with an automatic current limiting circuit.
4. Features:
   a. Housing: Enclose circuitry in a housing.
   b. Local Adjustment: Include screw adjustment on exterior of housing for dc voltage output.
   c. Mounting: DIN rail.
   d. Visual status indicator.
5. Performance:
   a. Input Voltage: Nominally 120 V ac, 60 Hz.
   b. Output Voltage: Nominally 24 V dc with plus or minus 1 V dc adjustment.
   c. Output Current: Minimum 100 mA.
   d. Load Regulation: Within 0.1 percent.
   e. Line Regulation: Within 0.05 percent.
   f. Stability: Within 0.1 percent of rated volts after warmup period.
   g. Ripple: 1 mV rms.

2.9 TEMPERATURE SENSORS

A. Description: Vibration and corrosion resistant; for wall, immersion, or duct mounting as required.

B. Platinum RTDs: Common Requirements:
1. 100 or 1000 ohms at zero deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
2. Two-wire, PTFE-insulated, 22-gage stranded copper leads.
3. Performance Characteristics:
   a. Range: Minus 40 to 210 deg F.
   b. Interchangeable Accuracy: At 32 deg F within 0.5 deg F.
   c. Repeatability: Within 0.5 deg F.
   d. Self-Heating: Negligible.
4. Transmitter Requirements:

a. Transmitter required for each 100-ohm RTD.
b. Transmitter optional for 1000-ohm RTD, contingent on compliance with end-to-end control accuracy.

C. Platinum RTD, Single-Point Air Temperature Duct Sensors:

1. Products: Subject to compliance with requirements, provide one of the following:
   a. Automation Components, Inc. (ACI)
   b. Dwyer
   c. MAMAC Systems, Inc.
   d. Approved performance equal.

2. 100 or 1000 ohms.
3. Temperature Range: Minus 40 to 210 deg F
4. Probe: Single-point sensor with a stainless-steel sheath.
5. Length: As required by application to achieve tip at midpoint of air tunnel, up to 18 inches (450 mm) long).
6. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
7. Gasket for attachment to duct or equipment to seal penetration airtight.
8. Conduit Connection: 1/2-inch (16-mm) trade size.)

D. Platinum RTD, Air Temperature Averaging Sensors:

1. Products: Subject to compliance with requirements, provide one of the following:
   a. Automation Components, Inc. (ACI)
   b. Dwyer
   c. MAMAC Systems, Inc.

2. 100 or 1000 ohms.
3. Temperature Range: Minus 40 to 210 deg F
4. Multiple sensors to provide average temperature across entire length of sensor.
5. Rigid probe of aluminum, brass, copper, or stainless-steel sheath.
6. Flexible probe of aluminum, brass, copper, or stainless-steel sheath and formable to a 4-inch radius.
7. Length: As required by application to cover entire cross section of air tunnel.
8. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
9. Gasket for attachment to duct or equipment to seal penetration airtight.
10. Conduit Connection: 1/2-inchPlatinum RTD Outdoor Air Temperature Sensors:

1. Products: Subject to compliance with requirements, provide one of the following:
   a. Automation Components, Inc. (ACI)
   b. Dwyer
   c. MAMAC Systems, Inc.
   d. Approved performance equal.

2. 100 or 1000 ohms.
3. Temperature Range: Minus 40 to 210 deg F (Minus 45 to 135 deg C).)
4. Probe: Single-point sensor with a stainless-steel sheath.

5. Solar Shield: Stainless steel.
6. Enclosure: NEMA 250, Type 4 or 4X junction box or combination conduit and outlet box with removable cover and gasket.
7. Conduit Connection: 1/2-inch (16-mm) trade size.

F. Platinum RTD Space Air Temperature Sensors:

1. Products: Subject to compliance with requirements, provide one of the following:
   a. Automation Components, Inc. (ACI)
   b. Kele
   c. MAMAC Systems, Inc.
   d. Approved performance equal.

2. 100 or 1000 ohms.
3. Temperature Range: Minus 40 to 210 deg F
4. Sensor assembly shall include a temperature sensing element mounted under a flush, brushed-aluminum cover.
5. Provide a mounting plate that is compatible with the surface shape that it is mounted to and electrical box used.
6. Concealed wiring connection.

G. Thermal Resistors (Thermistors): Common Requirements:
1. 10,000 ohms at 25 deg C and a temperature coefficient of 23.5 ohms/ohm/deg C.
2. Two-wire, PTFE-insulated, 22-gage stranded copper leads.
3. Performance Characteristics:
   a. Range: Minus 40 to 210 deg F.
   b. Interchangeable Accuracy: At 77 deg F within 0.5 deg F.
   c. Repeatability: Within 0.5 deg F.
   d. Drift: Within 0.5 deg F over 10 years.
   e. Self-Heating: Negligible.
4. Transmitter optional, contingent on compliance with end-to-end control accuracy.

H. Thermistor, Single-Point Duct Air Temperature Sensors:

1. Products: Subject to compliance with requirements, provide one of the following:
   a. Automation Components, Inc. (ACI)
   b. Dwyer
   c. MAMAC Systems, Inc.
   d. Approved performance equal.

2. Temperature Range: Minus 40 to 210 deg F
3. Probe: Single-point sensor with a stainless-steel sheath.
4. Length: As required by application to achieve tip at midpoint of air tunnel, up to 18 inches.
5. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
6. Gasket for attachment to duct or equipment to seal penetration airtight.
7. Conduit Connection: 1/2- inch trade size

I. Thermistor Averaging Air Temperature Sensors:

1. Products: Subject to compliance with requirements, provide one of the following:

a. Automation Components, Inc. (ACI)
b. Dwyer
c. MAMAC Systems, Inc.
d. Approved performance equal.

2. Temperature Range: Minus 40 to 210 deg F
3. Multiple sensors to provide average temperature across entire length of sensor.
4. Rigid probe of aluminum, brass, copper, or stainless-steel sheath.
5. Flexible probe of aluminum, brass, copper, or stainless-steel sheath and formable to a 4-inch radius.
6. Length: As required by application to cover entire cross section of air tunnel.
7. Enclosure: Junction box with removable cover; NEMA 250, Type 1 for indoor applications and Type 4 for outdoor applications.
8. Gasket for attachment to duct or equipment to seal penetration airtight.
9. Conduit Connection: 1/2-inch trade size.

J. Thermistor Outdoor Air Temperature Sensors:

1. Products: Subject to compliance with requirements, provide one of the following:
   a. Automation Components, Inc. (ACI)
   b. Dwyer
   c. MAMAC Systems, Inc.
   d. Approved performance equal.

2. Temperature Range: Minus 40 to 210 deg F
3. Probe: Single-point sensor with a stainless-steel sheath.
4. Solar Shield: Stainless steel.
5. Enclosure: NEMA 250, Type 4 or 4X junction box or combination conduit and outlet box with removable cover and gasket.
6. Conduit Connection: 1/2-inch trade size.

K. Thermistor Space Air Temperature Sensors:

a. Products: Subject to compliance with requirements provide one of the following:
b. Automation Components, Inc. (ACI)
c. Dwyer
d. MAMAC Systems, Inc.
e. Approved performance equal.

2. Temperature Range: Minus 40 to 210 deg F
3. Sensor assembly shall include a temperature sensing element mounted under a flush, brushed-aluminum cover.
4. Provide a mounting plate that is compatible with the surface shape that it is mounted to and electrical box used.
5. Concealed wiring connection.

L. Space Air Temperature Sensors for Use with DDC Controllers Controlling Terminal Units:
1. Platinum RTD or thermistor.

2. Thermistor:
   a. Pre-aged, burned in, and coated with glass; inserted in a metal sleeve; and entire unit encased in epoxy.
   b. Thermistor drift shall be less than plus or minus 0.5 deg F over 10 years.
3. Temperature Transmitter Requirements:
   a. Mating transmitter required with each 100-ohm RTD.
   b. Mating transmitters optional for 1000-ohm RTD and thermistor, contingent on compliance with end-to-end control accuracy.

4. Provide digital display of sensed temperature.

5. Provide sensor with local control.
   a. Local override to turn HVAC on.
   b. Local adjustment of temperature set point.
   c. Both features shall be capable of manual override through control system operator.

M. Liquid Temperature Sensors
1. RTD, Commercial Grade:
   a. Products: Subject to compliance with requirements, provide one of the following:
      1) Automation Components, Inc. (ACI)
      2) MAMAC Systems, Inc.
      3) Dwyer Instruments, Inc.
      4) Approved performance equal.
2. Description:
   a. Platinum with a value of 100 or 1000 ohms at 0 deg C and a temperature coefficient of 0.00385 ohm/ohm/deg C.
   b. Encase RTD in a stainless-steel sheath with a 0.25-inch OD.
   c. Sensor Length: 4, 6, or 8 inches as required by application.
   d. Process Connection: Threaded, NPS 1/2 (DN 15).
   e. Two-stranded copper lead wires.
   f. Powder-coated steel enclosure, NEMA 250, Type 4.
   g. Conduit Connection: 1/2-inch trade size.
   h. Performance Characteristics:
      1) Range: Minus 40 to 210 deg F.
      2) Interchangeable Accuracy: Within 0.50 deg F at 32 deg F.
   i. Thermowells, Commercial Grade:
      1) Stem: Straight shank formed from solid bar stock.
      2) Material: stainless steel.
      3) Process Connection: Threaded, NPS 3/4.
      4) Sensor Connection: Threaded, NPS 1/2.
      5) Bore: Sized to accommodate sensor with tight tolerance between sensor and well.
      6) Furnish thermowells installed in insulated pipes and equipment with an extended neck.
      7) Length: 4, 6, or 8 inches as required by application.

8) Thermowells furnished with heat-transfer compound to eliminate air gap between wall of sensor and thermowell and to reduce time constant.

N. Room sensor accessories include the following:

1. Insulating Bases: For sensors located on exterior walls.
2. Sensor Protective Guards: Locking; heavy-duty, transparent plastic; mounted on separate base.
3. Adjusting Key: As required for calibration and cover screws.

2.10 HUMIDITY SENSORS

A. Humidity Sensors: Bulk polymer sensor element.

1. Manufacturers; Subject to compliance with requirements, provide products by one of the following:
   a. Automation Components, Inc. (ACI)
   b. MAMAC Systems, Inc.
   c. ROTRONIC Instrument Corp.
   d. Vaisala.
   e. Approved performance equal.
2. Accuracy: 5 percent full range with linear output.
3. Analog Output: 4-20 mA
4. Room Sensor Measurement Range: 0 to 100 percent relative humidity.
5. Room Sensor Cover Construction: Manufacturer's standard locking covers.

   a. Set-Point Adjustment: Concealed.
   b. Set-Point Indication: Concealed.
   c. Thermometer: Concealed.
   d. Color: White.
   e. Orientation: Vertical.
6. Duct Sensor: 0 to 100 percent relative humidity measurement range with element guard and mounting plate.
7. Outside-Air Sensor: 0 to 100 percent relative humidity measurement range with mounting enclosure, suitable for operation at outdoor temperatures of minus 40 to plus 140 deg F.
8. Duct and Sensors: With element guard and mounting plate, range of 0 to 100 percent relative humidity.

2.11 PRESSURE SENSORS

A. Pressure Transmitters/Transducers:

1. Manufacturers; Subject to compliance with requirements, provide products by one of the following:
   a. Automation Components, Inc. (ACI)
   b. MAMAC Systems, Inc.
   c. ROTRONIC Instrument Corp.
   d. Setra
   e. Vaisala.
   f. Approved performance equal.

2. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
   a. Accuracy: 2 percent of full scale with repeatability of 0.5 percent.
   b. Output: 4 to 20 mA.
   c. Building Static-Pressure Range: 0- to 0.25-inch wg.
   d. Duct Static-Pressure Range: 0- to 5-inch wg.
3. Water Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig operating pressure; linear output 4 to 20 mA.
4. Water Differential-Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig operating pressure and tested to 300-psig; linear output 4 to 20 mA.
5. Pressure Transmitters: Direct acting for gas, liquid, or steam service; range suitable for system; linear output 4 to 20 mA.

B. Room sensor accessories include the following:

1. Insulating Bases: For sensors located on exterior walls.
2. Sensor Protective Guards: Locking; heavy-duty, transparent plastic; mounted on separate base.
3. Adjusting Key: As required for calibration and cover screws.

2.12 STATUS SENSORS

A. Status Inputs for Fans:
   1. Differential-pressure switch with pilot-duty rating and with adjustable range of 0- to 5-inch wg.
   2. Comply with ISA 50.00.01, current-sensing fixed- or split-core transformers with self-powered transmitter, adjustable and suitable for 175 percent of rated motor current.

B. Status Inputs for Pumps:
   1. Differential-pressure switch with pilot-duty rating and with adjustable pressure-differential range of 8 to 60 psig, piped across pump.
   2. Comply with ISA 50.00.01, current-sensing fixed- or split-core transformers with self-powered transmitter, adjustable and suitable for 175 percent of rated motor current.

C. Status Inputs for Electric Motors: Comply with ISA 50.00.01, current-sensing fixed- or split-core transformers with self-powered transmitter, adjustable and suitable for 175 percent of rated motor current.

D. Voltage Transmitter (100- to 600-V ac): Comply with ISA 50.00.01, single-loop, self-powered transmitter, adjustable, with suitable range and 1 percent full-scale accuracy.

E. Power Monitor: 3-phase type with disconnect/shorting switch assembly, listed voltage and current transformers, with pulse kilowatt hour output and 4- to 20-mA kW output, with maximum 2 percent error at 1.0 power factor and 2.5 percent error at 0.5 power factor.

F. Current Switches: Self-powered, solid-state with adjustable trip current, selected to match current and system output requirements.

G. Electronic Valve/Damper Position Indicator: Visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.

H. Differential-Pressure Switch (Air or Water): Snap acting, with pilot-duty rating and with suitable scale range and differential.

1. Manufacturers; Subject to compliance with requirements, provide products by one of the following:
   a. BEC Controls Corporation.
   b. I.T.M. Instruments Inc.
   c. Approved performance equal.

2.13 CARBON MONOXIDE SENSORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. MSA Z-Gard
   2. Dwyer GST Series
   3. Kele KGD Series
   4. Approved performance equal.

B. Description: Electrochemical measurement technology or equivalent technology that provides performance indicated, long-term stability, and reliability.
   1. Individual Sensor/Transmitter Applications: Each sensor/transmitter connected directly to DDC system.
   2. Multiple Sensor/Transmitters for Zoned Applications: Multiple sensor/transmitters arranged in zones as indicated on Drawings and directly connected to carbon monoxide monitoring system controller; furnished with sensors and transmitters as part of a complete system furnished by single manufacturer.

C. Performance:
   1. Carbon Monoxide Concentration Range: Zero to 100 ppm.
   2. Accuracy: Within 5 percent of full-scale range.
   3. Ambient Temperature: 0 to 104 deg F.

D. Sensor and Transmitter Output Signals:
   1. Analog Output Signal: 4 to 20 mA.

E. Sensor and Transmitter Construction:
   1. Enclosure: Painted metal or plastic
   2. Electrical Connections: Screw terminals.

F. Calibration Kit: Provide kit and turn over to Owner at start of warranty period.

2.14 CARBON DIOXIDE SENSORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Vaisala GMD Series (Duct Mount); GMW Series (Wall Mount)
   2. Veris CD2 Series (Duct Mount); CW2 Series (Wall Mount)
   3. Kele KCD Series
   4. Approved performance equal.

B. Description:
   1. NDIR or equivalent technology that provides performance indicated, long-term stability, and reliability.

C. Performance:
   1. Carbon Dioxide Concentration Range: Zero to 2000 ppm.
   2. Accuracy: Within 3 percent of reading, plus or minus 40 ppm.
   3. Response Time: Within 60 seconds.
   4. Warm-up Time: Within 3 minute(s).
   5. Ambient Relative Humidity: Zero to 95 percent noncondensing.
   6. Ambient Temperature: 32 to 122 deg F.

D. Output Signals:
   1. Analog Output Signal: 4 to 20 mA output signal, linearized to carbon dioxide concentration in parts per million (ppm).

E. Construction:
   1. Enclosure: Painted metal or plastic.
   2. Electrical Connections: Screw terminals.

F. Calibration Kit: Provide kit and turnover to Owner at start of warranty period.

2.15 LIQUID-LEVEL SENSORS AND TRANSMITTERS

A. Liquid-Level Sensors and Transmitters, Ultrasonic Type:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Flowline EchoTouch
      b. Approved performance equal.
   2. Description: Complete package with electronics unit and sensor.
      a. Non-contact continuous level measurement with an output signal that is proportional to level.
      b. No moving parts and no routine cleaning and recalibration necessary.
      c. Electronic unit integral to sensor.
   3. Performance:
      a. Range: 1 to 39.3 ft
      b. Span: Adjustable; varies with application. At least 20 percent beyond high- and low-level set point and alarm levels.
      c. Accuracy: Within greater than 0.2 percent of range or 0.2 inch.
      d. Repeatability: Within 0.12 inches
      e. Resolution: Within 0.12 inches
      f. Supply Voltage: 14 to 30 V dc.
      g. Maximum Electrical Load: 600 ohms at 24 V dc.
      h. Response Time: 0.30 seconds, adjustable.
      i. Pressure: 30 psig
      j. Ambient Temperature Range: Minus 40 to plus 158 deg F
      k. Free from effects of RF interference.
   4. Sensor:
      a. Material: PVDF
      b. Process Connection: NPS 2 NPT.
   5. Electronics Unit:
      a. Enclosure: NEMA 250, Type 4X.
      b. Material: Plastic with UV protection or powder-coated cast aluminum, explosion proof.
      c. Conduit Connection: NPS 1/2 trade size.

d. Two wire, loop powered.
e. Output Signal: 4 to 20 mA dc.
f. Fail-Safe Error Signals: User selectable; 4 to 20 mA or hold.
g. Local Display: LCD; minimum of two lines and seven digits. Display of level in units indicated on Drawings.
h. Operator Interface: Keypad or through touchscreen display; located on face of unit.
i. Temperature Compensation: Automatic and readable for display.

2.16 OUTSIDE AIR QUALITY MEASURING STATION

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Orion AQM – Complete
   b. Oizom Polludrone
   c. Approved performance equal

B. Description:
1. Integrated air quality monitoring system designed for building automation, environmental compliance, and research applications. Air quality station shall provide real-time measurements of particulate matter and gaseous pollutants, along with meteorological parameters.

C. Performance:
1. Particulate Matter:
   a. Size Range:
      1) PM2.5: 0.6–2.5 µm
      2) PM10: 0.6–10 µm
   b. Concentration Range:
      1) PM1/PM2.5: 0–1000 µg/m³
      2) PM10: 0–2500 µg/m³
   c. Detection Limit: 0.1 µg/m³
   d. Accuracy:
      1) PM1: ±2 µg/m³
      2) PM2.5: ±3 µg/m³
      3) PM10: ±4 µg/m³
2. Gaseous Pollutants:
   a. Nitrogen Dioxide (NO2), Nitric Oxide (NO), Carbon Monoxide (CO), Ozone (O2)
   b. Concentration Range:
      1) NO2, NO, O2: 0–2000 ppb
      2) CO: 0–10,000 ppb
   c. Detection Limit:
      1) NO2, NO, O2: 5 ppb
      2) CO: 10 ppb
   d. Accuracy:
      1) NO2 ±5 ppb
      2) NO: ±8 ppb
      3) O_3: ±6 ppb
      4) CO: ±183 ppb
3. Meteorological Parameters:

a. Temperature: ±0.5°F at 68°F
b. Humidity: ±3% RH (0–90%), ±5% RH (90–100%)
c. Barometric Pressure: ±0.44 inHg

D. Construction:
1. Enclosure: IP65-rated, weather-resistant
2. Operating Temperature: -22°F to +115°F
3. Operating Humidity: 15–100% RH, non-condensing
4. Air quality measuring station shall be installed per manufacture installation requirements. Provide protective measures and select installation location to ensure measuring station is shielded from direct sunlight.

E. Communication:
1. Protocols Supported: Modbus, BACnet, DNP3, SNMP

2.17 Refrigerant Vapor Detection System

A. Provide a refrigerant vapor detection system to meet the latest version of ASHRAE 15 and the applicable local codes. The system shall sample and monitor a minimum of two (2) remote sampling points per Chiller.

B. Provide the following accessories:
1. One alarm relay for each level of alarm and one relay for flow failure or horn silence. Failure relay output that shall energize upon failure of monitor system operation. Failures include but are not limited to the following: low airflow through monitor, power circuit failure, and a saturated or absent sensor signal.
2. Analog Output 4-20 mA or 0-5 VDC.
3. Enclosure type: NEMA 4X.

C. Sampling Tubing shall be Type L or hard drawn copper tubing.

D. The read out/control unit shall be wall mounted pursuant with contract drawings. Remote sampling points shall be located within the central plant area according to the drawings.

2.18 WATER FLOW METERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Onicon F-3200 Series
2. Approved performance equal.

B. Description: In-line body flow meter using electromagnetic technology.
1. No moving parts.
2. Continuous auto-zero function.
3. Inherent bidirectional flow measurement.
4. Flow-measurement applications with three pipe diameters upstream and two pipe diameters downstream.

C. Factory Calibration: Wet calibrate each meter to standards traceable to NIST. Tag each meter and provide each meter with a certificate of calibration.

D. Performance:
1. Ambient Temperature: Minus 4 to plus 140 deg F.
2. Conductivity: Suitable for flow measurement of fluids with electrical conductivity greater than 5 microseimens per centimeter.

3. Flow Velocity Range: 0.1 to 33 fps.
4. Flow Accuracy: Within 0.2 percent of reading for flow velocities between 1.6 to 33 fps and within 0.0033 fps of reading for flow velocities 1.6 fps and less.
5. Process Pressure and Temperature: Suitable for system maximum operating pressure and temperature.
6. Pressure Drop: No permanent pressure drop.

E. Analog Output Current Signal:
1. Two-wire, 4 to 20 mA dc current source.
2. Isolated.
3. Digital Output Signal: Two, programmable, digital/pulse outputs configurable for frequency, pulse, or directional flow.
4. Communication Interface: BACnet IP or BACnet MS/TP capable with associated flow meter display.
5. Operator Interface: Keypad with backlit digital display.
   a. Each flow meter shall be factory programmed for its specific application and shall be re-programmable using the integral keypad on the converter (no special interface device or computer required). Each flow meter shall be covered by the manufacturer's two-year warranty.
6. Multiple-line digital display of alphanumerical characters.
7. LED for normal and alarm operation.

F. Construction:
1. Body Material: Epoxy-coated carbon steel.
2. PTFE body liner offers better performance over larger size and temperature range. Consult manufacturer for other liner options.
3. Body Liner Material: Polypropylene or Ebonite for low temperature service, PFTE for hot water service.
4. Flow Tube Material: Type 304 or 316 stainless steel.
5. Body End Connections: ASME B16.5, Class 150 or 300 as required by pressure and temperature.
6. Electrodes: Type 316 stainless steel. Quantity determined by manufacturer based on application.
7. Electronics Enclosure:
   a. Location: Integral or remote from meter body.
   b. Material: Painted aluminum.
   c. Removable cover.
   d. Rating: NEMA 250, Type 4, 4X, or 6.
8. For installations in non-metallic pipe, install grounding rings between flanges.

2.19 THERMAL ENERGY METER WITH IN-LINE ELECTROMAGNETIC FLOW SENSOR

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Onicon System-10
2. Approved performance equal.

B. Description:
1. Factory-packaged meter consisting of supply and return temperature sensors, flow sensor, digital display, keypad user interface, installation hardware, color-coded interconnecting cabling, and installation instructions.

2. Factory calibrate each thermal energy meter and provide with calibration certification traceable to NIST.

C. Performance:
1. Ambient Operating Temperature: Minus 20 to plus 140 deg F.
2. Energy Calculation Nonlinearity: Within 0.05 percent.
3. Fluid Electrical Conductivity: Suitable for fluids with electrical conductivity greater than 5 microseimens per centimeter.
4. Flow Sensor: Refer to Section “WATER FLOW METERS” for flow sensor requirements.
5. Process Pressure and Temperature: Suitable for system maximum operating pressure and temperature.
6. Process Temperature Accuracy: Differential temperature accuracy within 0.15 deg F over the calibrated range.

D. Meter Display: Backlit, LCD alphanumeric display of the following on face of meter enclosure:
1. Total energy consumption.
2. Energy rate.
3. Flow rate.
4. Supply temperature.
5. Return temperature.
6. Visual indication of power status (on/off) on face of enclosure.

E. Meter Electronics Enclosure:
1. Remote mounted from temperature and flow sensors.
2. Indoor Applications: NEMA 250, Type 4 or 13.
3. Outdoor Applications: NEMA 250, Type 4.
4. Labeled terminal strip for field wiring connections.
5. Connections: Suitable for mating to field-installed conduit.

F. Power Supply:
1. Field Power: 24, 120, 240 V ac, 50 or 60 Hz as required by the application.
2. Internal Power: As required by flow meter.

G. Programming:
1. Factory programmed for specific application and field programmable through keypad on face of enclosure.
2. Programmed parameters and total energy consumption stored in non-volatile EEPROM memory.

H. Output Signals:
1. Total Energy Consumption: Isolated solid-state dry contact with 100 mA, 50 V rating and contact duration of 0.5, 1, 2, or 6 seconds.
2. Energy Rate, Flow Rate, Supply Temperature, Return Temperature: 4 to 20 mA or zero to 10 V dc for each.
3. Communication Interface: BACnet IP or BACnet MS/TP capable to share total energy consumption, energy rate, flow rate, and supply and return temperature data.

I. Temperature Sensors:
1. Enclosure: NEMA 250, Type 4 with conduit connections.
2. Sensor Cable: As required by manufacturer for application.
3. Temperature Range: Matched pair; suitable for application.

2.20 DUCT AIR FLOW MEASURING STATIONS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. EBTRON, Inc.
   2. Onicon Incorporated.
   3. Approved performance equal.

B. General:
   1. Provide an EBTRON, Inc. model GTx116-P+ duct airflow measuring station.
   2. Airflow measurement devices shall use the principle of thermal dispersion and provide one self-heated bead-in-glass thermistor and one zero power bead-in-glass thermistor at each sensing node.
      a. Thermal dispersion devices that indirectly heat a thermistor are not acceptable.
   3. Substitution requests for acceptance less than 60 days prior to bid date or products submitted in non-conformance with the requirements of this specification will not be considered.
      a. For any product to be considered for substitution, a written document shall be submitted to the engineer detailing exceptions and compliance, section-by-section with supporting documentation, before an approval will be considered.
      b. Any product submitted as an equal shall be expected to comply with all performance capabilities and functional aspects of this specification.
   4. Excluded devices.
      a. Fan Inlet airflow measurement devices.
      b. Measurement technologies using chip-in-glass, chip-in-epoxy or other chip type thermistors for the heated sensor component are not acceptable.
      c. Pitot tubes, Pitot arrays, Piezo rings and other differential pressure-based devices are not acceptable.
      d. Vortex shedding devices are not acceptable.

C. Required product performance:
   1. Airflow Measurement Devices (AMD) with Temperature Output and Airflow Alarming Capability
   2. General
      a. Provide one AMD for each measurement location provided on the plans, schedules and/or control diagrams to determine the average airflow rate and temperature at each measurement location.
      b. Each AMD shall be provided with a microprocessor-based transmitter and one or more sensor probes.
         1) Devices that have electronic signal processing components on or in the sensor probe are not acceptable.
      c. Airflow measurement shall be field configurable to determine the average Actual or Standard mass airflow rate.
         1) Actual airflow rate calculations shall have the capability of being corrected by the transmitter for altitudes other than sea level.
      d. Temperature measurement shall be field configurable with velocity weighted average as the default, or manual selection of arithmetic average temperature.
   3. Sensor Probes

a. Sensor probes shall be constructed of gold anodized, 6063 aluminum alloy tube, 316 stainless steel tube are available when required.
b. Sensor probe mounting brackets shall be constructed of 304 stainless steel.
c. Probe internal wiring between the connecting cable and sensor nodes shall be Kynar coated copper.
    1) PVC jacketed internal wiring is not acceptable.
d. Probe internal wiring connections shall consist of solder joints and spot welds.
    1) Internal wiring connections shall be sealed and protected from the elements. They shall be capable of direct exposure to water without affecting instrument operation.
    2) Connectors of any type within the probe are not acceptable.
    3) Printed circuit boards within the probe are not acceptable.
e. Each sensor probe shall be provided with an integral, FEP jacket, plenum rated CMP/CL2P, UL/cUL Listed cable rated for exposures from -67°° F to 392°° F (-55°° C to 200°° C) and continuous and direct UV exposure.
    1) Plenum rated PVC jacket cables are not acceptable.
f. Each sensor probe cable shall be provided with a connector plug with gold plated pins for connection to the transmitter.
g. Each sensor probe shall contain one or more independently wired sensing nodes.
h. Sensor node airflow and temperature calibration data shall be stored in a serial memory chip in the cable connecting plug and not require matching or adjustments to the transmitter in the field.
i. Each sensor node shall be provided with two bead-in-glass, hermetically sealed thermistors potted in a marine grade waterproof epoxy with sensor housings constructed of glass-filled polypropylene. Upon request, the manufacture shall provide a written independent laboratory test result of 100% survival rate in a 30-day saltwater and acid vapor test.
    1) Devices that use epoxy or glass encapsulated chip thermistors are not acceptable.
    2) Devices with exposed leads are not acceptable.
j. Each thermistor shall be individually calibrated at a minimum of 3 temperatures to NIST-traceable temperature standards.
k. Each sensor node shall be individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard and have an accuracy of ±±2% of reading over the entire calibrated airflow range of 0 to 5,000 FPM.
    1) Upon request the manufacturer shall submit for AMD approval a copy of the NIST report of calibration used for the reference standard used.
        a) Devices claiming NIST traceability to third party laboratories and not directly to NIST are not acceptable.
        b) Devices calibrated against standards other than the NIST LDA are not acceptable.
l. Accuracy shall include the combined uncertainty of the sensor nodes and transmitter.

m. The installed airflow accuracy shall be:
   1) Ducts - ±±3% of reading when installed in accordance with the manufacturers' recommended placement guidelines.
   2) Non-ducted Outdoor Air intakes ÓÓ better than or equal to ±±5% of reading when installed in accordance with the manufacturers' recommended placement guidelines.
n. Devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter shall demonstrate compliance with this requirement over the entire operating range.
o. Each sensing node shall have a temperature accuracy of ±±0.15°° F (0.08°° C) over an operating range of -20°° F to 160°° F. (-28.9°° C to 71.1°° C) and humidity range of 0 to 100% RH.

4. Transmitter
   a. A remotely located microprocessor-based transmitter shall be provided for each measurement location.
   b. The transmitter shall be comprised of a main circuit board and interchangeable interface card.
   c. All printed circuit board interconnects, edge fingers, receptacle plug pins and PCB test points shall be gold plated.
   d. All printed circuit boards shall be electroless nickel immersion gold (ENIG) plated.
   e. All integrated circuitry shall be temperature rated as ÜÜindustrial-grade¢¢. Submissions containing ÜÜcommercial-grade¢¢ integrated circuitry are not acceptable.
   f. The transmitter shall be capable of determining the airflow rate and temperature average of all connected sensor nodes in an array for a single location.
      1) Separate integration buffers shall be provided for display airflow output, airflow signal output (analog and network) and individual sensor output (IR-interface).
   g. The transmitter shall be capable of providing a high and/or low airflow alarm with user-defined set point and % of set point tolerance. Alarm shall be capable of being manually or automatically reset and low-limit cutoff value may be selected to disable the alarm. An alarm delay function shall also be field defined.
   h. The transmitter shall be capable of identifying an AMD malfunction via the system status alarm and ignore any sensor node that is in a fault condition.
   i. The transmitter shall be capable of field configuration, diagnostics and include Field Output Adjustment Wizard that allows for a one- or two-point field adjustment to factory calibration for installations that require adjustment.
   j. The transmitter shall be provided with a 16-character, alpha-numeric, LCD display.
   k. The transmitter shall be provided with two field selectable (0-5/0-10 VDC or 4-20mA), scalable, isolated and over-current protected analog output signals (AO1=airflow, AO2=temperature or alarm), in combination with either of the following:
      1) one isolated RS-485 (field selectable BACnet MS/TP or Modbus RTU) network connection

2) one isolated Ethernet (simultaneously supported BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection.

l. The analog signal capability shall include two output terminals: the first (AO1), shall provide the total airflow rate and the second output (AO2) shall be field configurable to provide temperature information.

m. The transmitter shall also be available with a single isolated LonWorks Free Topology network interface. Transmitters shall be available alternatively with one USB connection for thumb-drive data logging of sensor data. Neither of these options shall include analog output signals.

n. The network communications RS-485 (BACnet MS/TP or Modbus RTU) or Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) shall provide: the average airflow rate, temperature, hi and/or low airflow set point alarm, system status alarm, individual sensor node airflow rates and individual sensor node temperatures. Individual node airflow rates and temperatures shall NOT be available via the network with Lon.

o. The transmitter shall have an on-off power switch. Isolation transformers shall not be required.

p. The transmitter shall be powered by 24 VAC (22.8 to 26.4 under load) @20 V-A maximum and use a switching power supply that is over-current and over-voltage protected.

q. The transmitter shall use a ÓÓwatchdog timer circuit to ensure automatic reset after power disruption, transients and brown-outs.

r. Each transmitter shall have an operating temperature range of -20°° F to 120°° F (-28.9°° C to 48.9°° C) and humidity range of 5 to 95% RH.

5. Listings and Certifications

a. The AMD shall be UL/cUL 873 Listed as an assembly.

1) Devices claiming compliance with the UL Listing based on individual UL component listing are not acceptable.

b. All network-capable AMD models supplied with RS-485 interface and BACnet protocol shall be BTL Listed.

c. The AMD shall be tested for compliance with the EMC Directive¢¢s requirements and be certified to carry the CE Mark for European Union Shipments.

6. Installation

a. Install in accordance with manufacturer¢¢s placement guidelines. A written report shall be submitted to the consulting mechanical engineer if any discrepancies are found.

2.21 FAN AIR FLOW MEASURING STATIONS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. EBTRON, Inc.
2. Onicon Incorporated.
3. Approved performance equal.

B. General

1. Provide an EBTRON, Inc. model GTx108-F fan airflow measuring device.

2. Airflow measurement devices shall use the principle of thermal dispersion and provide one self-heated bead-in-glass thermistor and one zero power bead-in-glass thermistor at each sensing node.
    a. Thermal dispersion devices that indirectly heat a thermistor are not acceptable.
3. Substitution requests for acceptance less than 60 days prior to bid date or products submitted in non-conformance with the requirements of this specification will not be considered.
    a. For any product to be considered for substitution, a written document shall be submitted to the engineer detailing exceptions and compliance, section-by-section with supporting documentation, before an approval will be considered.
    b. Any product submitted as an equal shall be expected to comply with all performance capabilities and functional aspects of this specification.
4. Excluded devices.
    a. Fan Inlet airflow measurement devices.
    b. Measurement technologies using chip-in-glass, chip-in-epoxy or other chip-type thermistors for the heated sensor component are not acceptable.
    c. Vortex shedding devices are not acceptable.

C. Required product performance.
1. Airflow Measurement Devices (AMD) with Temperature Output and Airflow Alarming Capability
2. General
    a. Provide one AMD for each measurement location provided on the plans, schedules and/or control diagrams to determine the average airflow rate and temperature at each measurement location.
    b. Each AMD shall be provided with a microprocessor-based transmitter and one or more sensor probes.
        1) Devices that have electronic signal processing components on or in the sensor probe are not acceptable.
    c. Airflow measurement shall be field configurable to determine the average Actual or Standard mass airflow rate.
        1) Actual airflow rate calculations shall have the capability of being corrected by the transmitter for altitudes other than sea level.
    d. Temperature measurement shall be field configurable with velocity weighted average as the default, or manual selection of arithmetic average temperature.
3. Sensor probes
    a. Sensor probes shall consist of one sensor node mounted on a 304 stainless steel block with two adjustable zinc plated steel rods connected to 304 stainless steel pivoting mounting feet.
    b. Sensor node internal wiring connections shall be sealed and protected from the elements and suitable for direct exposure to water.
    c. Each sensor probe shall be provided with an integral, FEP jacket, plenum rated CMP/CL2P, UL/cUL Listed cable rated for exposures from -67°°F to 392 °°F (-55°° C to 200°° C) and continuous and direct UV exposure.
        1) Plenum rated PVC jacket cables are not acceptable.

d. Each sensor probe cable shall be provided with a connector plug with gold plated pins for connection to the transmitter.
e. Sensor node airflow and temperature calibration data shall be stored in a serial memory chip in the cable connecting plug and not require matching or adjustments to the transmitter in the field.
f. Each sensor node shall be provided with two bead-in-glass, hermetically sealed thermistors potted in a marine grade waterproof epoxy with sensor housings constructed of glass-filled polypropylene. Upon request, the manufacture shall provide a written independent laboratory test result of 100% survival rate in a 30-day saltwater and acid vapor test.
    1) Devices that use epoxy or glass encapsulated chip thermistors are not acceptable.
    2) Devices with exposed leads are not acceptable.
g. Each thermistor shall be individually calibrated at a minimum of 3 temperatures to NIST-traceable temperature standards.
h. Each sensor node shall be individually calibrated at 16 measurement points to airflow standards directly calibrated at NIST to the NIST Laser Doppler Anemometer (LDA) primary velocity standard and have an accuracy of ±±2% of reading over the entire calibrated airflow range of 0 to 10,000 FPM.
    1) Upon request the manufacturer shall submit for AMD approval a copy of the NIST report of calibration used for the reference standard used.
        a) Devices calibrated against standards other than the NIST LDA or against NIST temperature standards only are not acceptable.
    2) Accuracy shall include the combined uncertainty of the sensor nodes and transmitter.
    3) Devices whose overall accuracy is based on individual accuracy specifications of the sensor probes and transmitter shall demonstrate compliance with this requirement over the entire operating range.
i. Each sensing node shall have a temperature accuracy of ±±0.15°° F (0.08°° C) over an operating range of -20°° F to 160°° F (-28.9°° C to 71.1°° C) and humidity range of 0 to 100% RH.
j. The number of independent sensor nodes provided shall be as follows:
    1) SWSI and DWDI fans: 2 probes x 1 sensor node/per probe in each fan inlet
    2) Fan Arrays (1 to 8 fans): 2 probes x 1 sensor node probe in each fan inlet

4. Transmitter
    a. A remotely located microprocessor-based transmitter shall be provided for each measurement location.
    b. The transmitter shall be comprised of a main circuit board and interchangeable interface card.
    c. All printed circuit board interconnects, edge fingers, and test points shall be gold plated.
    d. All printed circuit boards shall be electroless nickel immersion gold (ENIG) plated.

e. All integrated circuitry shall be temperature rated as ÜÜindustrial-grade¢¢. Submissions containing ÜÜcommercial-grade¢¢ integrated circuitry are not acceptable.
f. The transmitter shall be capable of determining the airflow rate and temperature of each fan.
   1) Separate integration buffers shall be provided for display airflow output, airflow signal output (analog and network) and individual sensor output (IR-interface).
g. The transmitter shall have startup firmware to facilitate setup of multiple fans and fan areas.
h. The transmitter shall be capable of providing a low and/or high airflow set point alarm.
i. The transmitter shall be capable of providing individual fan alarming on fan array configurations.
j. The transmitter shall be capable of identifying an AMD malfunction via the system status alarm and ignore any sensor node that is in a fault condition.
k. The transmitter shall be capable of field configuration, diagnostics and include Field Output Adjustment Wizard that allows for a one- or two-point field adjustment to factory calibration for installations that require adjustment.
l. The transmitter shall be provided with a 16-character, alpha-numeric, LCD display.
m. The transmitter shall be provided with two field selectable (0-5/0-10 VDC or 4-20mA), scalable, isolated and over-current protected analog output signals (AO1=airflow, AO2=temperature or alarm), in combination with either of the following:
   1) One isolated RS-485 (field selectable BACnet MS/TP or Modbus RTU) network connection
   2) One isolated Ethernet (simultaneously supported BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) network connection.
n. Analog signal capability shall include two output terminals: the first (AO1), shall provide the total airflow rate, while the second output (AO2) shall be field configurable to provide temperature.
o. The transmitter shall also be available with a single isolated LonWorks Free Topology network interface. Transmitters shall be available alternatively with one USB connection for thumb-drive data logging of sensor data. Neither of these options shall include analog output signals.
p. Network communications RS 485 (BACnet MS/TP or Modbus RTU) or Ethernet (BACnet Ethernet or BACnet IP, Modbus TCP and TCP/IP) shall provide: the average airflow rate, temperature, hi and/or low airflow set point alarm, system status alarm, individual sensor node airflow rates and individual sensor node temperatures. Individual node airflow rates and temperatures shall be available via the network with Lon.
q. The transmitter shall have an on-off power switch. Isolation transformers shall not be required.
r. The transmitter shall be powered by 24 VAC (22.8 to 26.4 under load) @16 V-A maximum and use a switching power supply that is over-current and over-voltage protected.

s. The transmitter shall use a ÓÓwatchdog timer circuit to ensure automatic reset after power disruption, transients and brown-outs.
t. Each transmitter shall have an operating range of -20°° F to 120°° F (-28.9°° C to 48.9°° C) and humidity range of 5 to 95% RH.

5. Listing and Certifications
   a. The AMD shall be UL/cUL 873 Listed as an assembly.
      1) Devices claiming compliance with the UL Listing based on individual UL component listing are not acceptable.
   b. All network-capable AMD models supplied with RS-485 interface and BACnet protocol shall be BTL Listed
6. Installation
   a. Install in accordance with manufacturer¢¢s placement guidelines. A written report shall be submitted to the consulting mechanical engineer if any discrepancies are found.

2.22 THERMOSTATS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Erie Controls.
   2. Danfoss Inc.; Air-Conditioning and Refrigeration Div.
   3. Heat-Timer Corporation.
   4. Honeywell Controls.
   5. Sauter Controls Corporation.
   6. tekmar Control Systems, Inc.
   7. Theben AG - Lumilite Control Technology, Inc.

B. Electric, solid-state, microcomputer-based room thermostat with remote sensor.
   1. Automatic switching from heating to cooling.
   2. Preferential rate control to minimize overshoot and deviation from set point.
   3. Set up for four separate temperatures per day.
   4. Instant override of set point for continuous or timed period from 1 hour to 31 days.
   5. Short-cycle protection.
   6. Programming based on every day of week.
   7. Selection features include degree F or degree C display, 12- or 24-hour clock, keyboard disable, remote sensor, and fan on-auto.
   8. Battery replacement without program loss.
   9. Thermostat display features include the following:
      a. Time of day.
      b. Actual room temperature.
      c. Programmed temperature.
      d. Programmed time.
      e. Duration of timed override.
      f. Day of week.
      g. System mode indications include "heating," "off," "fan auto," and "fan on."

C. Low-Voltage, On-Off Thermostats: NEMA DC 3, 24-V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed set-point adjustment, 55 to 85 deg F set-point range, and 2 deg Fmaximum differential.

D. Line-Voltage, On-Off Thermostats: Bimetal-actuated, open contact or bellows-actuated, enclosed, snap-switch or equivalent solid-state type, with heat anticipator; listed for electrical rating; with concealed set-point adjustment, 55 to 85 deg F set-point range, and 2 deg F maximum differential.
   1. Electric Heating Thermostats: Equip with off position on dial wired to break ungrounded conductors.
   2. Selector Switch: Integral, manual on-off-auto.

E. Remote-Bulb Thermostats: On-off or modulating type, liquid filled to compensate for changes in ambient temperature; with copper capillary and bulb, unless otherwise indicated.
   1. Bulbs in water lines with separate wells of same material as bulb.
   2. Bulbs in air ducts with flanges and shields.
   3. Averaging Elements: Copper tubing with either single- or multiple-unit elements, extended to cover full width of duct or unit; adequately supported.
   4. Scale settings and differential settings are clearly visible and adjustable from front of instrument.
   5. On-Off Thermostat: With precision snap switches and with electrical ratings required by application.
   6. Modulating Thermostats: Construct complete potentiometer coil and wiper assembly is removable for inspection or replacement without disturbing calibration of instrument.

2.23 HUMIDISTATS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. MAMAC Systems, Inc.
   2. ROTRONIC Instrument Corp.

B. Duct-Mounting Humidistats: Electric insertion, 2-position type with adjustable, 2 percent throttling range, 20 to 80 percent operating range, and single- or double-pole contacts.

2.24 RELAYS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Functional Devices
   2. ROTRONIC Instrument Corp.
   3. Approved performance equal.

B. General Requirements:
   1. UL listed.
   2. Rated for at least 10 A at 250 V ac and 60 Hz.
   3. SPDT, DPDT, or three-pole double-throw, as required by control application.
   4. Construct contacts of silver, silver alloy, or gold.
   5. Enclose relay in a polycarbonate dust-tight cover.
   6. Include LED indication.
   7. Performance:
      a. Mechanical Life: At least 10 million cycles.
      b. Ambient Operating Temperatures: Minus 30 to 115 deg F.

8. Equip relays with coil transient suppression to limit transients to non-damaging levels.
9. Plug each relay into industry-standard, 35 mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
10. Include relay socket with screw terminals. Mold into socket the coincident screw terminal numbers.

2.25 ACTUATORS

A. Electric Motors: Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Belimo Aircontrols (USA), Inc.
      b. Siemens.
      c. Johnson Controls.
      d. Alerton.
      e. Delta Controls.
      f. IMI TA / Victaulic.

   2. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."
   3. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.
   4. Nonspring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
   5. Spring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running and breakaway torque of 150 in. x lbf.
   6. Nonspring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
   7. Spring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running and breakaway torque of 150 in. x lbf.
   8. Smoke Dampers:
      a. Size for torque required for damper seal at load conditions with one actuator per damper section. Mechanically paralleled or 'piggybacked' actuators are not permitted.
      b. Coupling: V-bolt dual nut clamp with a V-shaped toothed cradle. Aluminum clamps or set screws are not acceptable.
      c. Overload Protection: Microprocessor or an electronic based motor controller providing burnout protection if stalled before full rotation is reached. The actuator shall be electronically cut off at full open to eliminate noise generation with the holding noise level to be inaudible.
      d. Power Requirements: 0.23A (running) and 0.09A (holding) at 24V-ac or 27 VA (running) and 10 VA (holding) at 120V-ac.
      e. Actuator timing shall be 15 seconds or as required by local codes, whichever is more stringent.
      f. Temperature Rating: Actuator shall have a UL555S listing by the damper manufacturer for 350ººF.

g. Proportional Smoke Damper Actuators shall meet all requirements specified above and shall modulate 0-100% open in response to a 2-10vdc or 4-20mA control signal. A 2-10vdc feedback output shall provide a 2-10vdc signal for position indication.
   1) Power Requirements (Proportional): Maximum (running) 12 VA at 24-V ac or 8 W at 24-V dc. Maximum (holding) 5VA at 24-V ac or 3 W at 24-V dc.
   2) A manual override winder and locking mechanism shall be provided for override operation of the actuator on a loss of power.

9. Combination Fire Smoke Dampers:
   a. Size for torque required for damper seal at load conditions.
   b. Coupling: V-bolt dual nut clamp with a V-shaped toothed cradle. Aluminum clamps or set screws are not acceptable.
   c. Overload Protection: Microprocessor or an electronic based motor controller providing burnout protection if stalled before full rotation is reached. The actuator shall be electronically cut off at full open to eliminate noise generation with the holding noise level to be inaudible.
   d. Power Requirements: 0.23A (running) and 0.09A (holding) at 24V-ac or 27 VA (running) and 10 VA (holding) at 120V-ac.
   e. Actuator timing shall be 15 seconds or as required by local codes, whichever is more stringent.
   f. Temperature Rating: Actuator shall have UL555 and UL555S listings by the damper manufacturer for 350ººF.
   g. Proportional Combination Fire and Smoke Damper Actuators shall meet all requirements specified above and shall modulate 0-100% open in response to a 2-10vdc or 4-20mA control signal. A 2-10vdc feedback output shall provide a 2-10vdc signal for position indication.
      1) Power Requirements (Proportional): Maximum (running) 12 VA at 24-V ac or 8 W at 24-V dc. Maximum (holding) 5VA at 24-V ac or 3 W at 24-V dc.
      2) A manual override winder and locking mechanism shall be provided for override operation of the actuator on a loss of power.

B. Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Belimo Aircontrols (USA), Inc.
   b. Honeywell Controls Inc.
2. Valves: Size for torque required for valve close off at maximum pump differential pressure.
3. Dampers: Size for running torque calculated as follows:
   a. Parallel-Blade Damper with Edge Seals: 7 inch-lb/sq. ft. of damper.
   b. Opposed-Blade Damper with Edge Seals: 5 inch-lb/sq. ft. of damper.
   c. Parallel-Blade Damper without Edge Seals: 4 inch-lb/sq. ft of damper.
   d. Opposed-Blade Damper without Edge Seals: 3 inch-lb/sq. ft. of damper.
   e. Dampers with 2- to 3-Inch wg of Pressure Drop or Face Velocities of 1000 to 2500 fpm: Increase running torque by 1.5.

f. Dampers with 3- to 4-Inch wg of Pressure Drop or Face Velocities of 2500 to 3000 fpm: Increase running torque by 2.0.

4. Coupling: V-bolt and V-shaped, toothed cradle.
5. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
6. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on nonspring-return actuators.
7. Power Requirements (Two-Position Spring Return): 24 or 120-V ac.
8. Power Requirements (Modulating): Maximum 25 VA at 24-V ac or 8 W at 24-V dc.
9. Proportional Signal: 0- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
10. Temperature Rating: Minus 22 to plus 122 deg F.
11. Temperature Rating (Smoke Dampers): Minus 22 to plus 250 deg F.
12. Run Time: 12 seconds open, 5 seconds closed.
13. The manufacturer shall provide 5-year limited warranty from the date of sale covering defects in material or workmanship.
14. All actuators are to be delivered with a detailed written installation instruction.

2.26 CONTROL VALVES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Belimo Aircontrols (USA), Inc.
2. Siemens.
3. Johnson Controls.
4. Schneider Electric.
5. IMI TA / Victaulic Modulator, Fusion P, Compact P.

B. Control Valves: Factory fabricated, of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated.

C. Hydronic System Characterized Ball valves shall have the following characteristics:
1. 2" and Smaller: Nickel-plated forged brass body rated at no less than 400 psi, stainless steel ball and blowout proof stem, female NPT end fittings, with a dual EPDM O-ring packing design, fiberglass reinforced Teflon seats, and a TEFZEL or stainless-steel flow characterizing disc.
2. 2-1/2" through 6": GG25 cast iron body, ANSI 125, class B, stainless steel ball and blowout proof stem, flange to match ANSI 125 with a dual EPDM O-ring package design, PTFE seats, and a stainless-steel flow characterizing disc.
3. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system (pump) head for two-way valves and 100 percent of pressure differential across valve or 100 percent of total system (pump) head.
4. Sizing: 5-psig maximum pressure drop at design flow rate or the following:
a. Two Position: Line size.
b. Two-Way Modulating: Twice the load pressure drop, but not more than value specified above.
c. Three-Way Modulating: Twice the load pressure drop, but not more than value specified above.

5. Valve assemblies shall be maintenance free.

D. Hydronic System Globe valves shall have the following characteristics:
1. NPS 2 and Smaller: Class 250 bronze body, bronze trim, rising stem, renewable composition disc, and screwed ends with back-seating capacity re-packable under pressure.
2. NPS 2-1/2 and Larger: Class 125 iron body, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.
3. Internal Construction: Replaceable plugs and stainless steel or brass seats.
   a. Single-Seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom.
   b. Double-Seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom.
4. Sizing: 5-psig maximum pressure drops at design flow rate or the following:
   a. Two Position: Line size.
   b. Two-Way Modulating: Twice the load pressure drop, but not more than value specified above.
   c. Three-Way Modulating: Twice the load pressure drop, but not more than value specified above.
5. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.
6. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system (pump) head for two-way valves and 100 percent of pressure differential across valve or 100 percent of total system (pump) head.
7. Two- and three-way globe valves shall be used only if characterized control valves do not fit the sizing criteria or application.

E. Hydronic System Butterfly Valves: Resilient Seat shall have the following characteristics:
1. NPS 2 to 12: Valve body shall be full lugged ductile 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. The shaft shall be supported at four locations by RPTFE bushings. A coated disc shell is not acceptable.
2. NPS 14 and Larger: Valve body shall be full lugged ductile 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 a dual-pin method to prevent the disc from settling onto the liner. The shaft shall be supported at four locations by RPTFE bushings. A coated disc shell is not acceptable.
3. Sizing: Two-Position (on/off) butterfly valves shall be sized using the 900 Cv rating. Modulating butterfly valves shall be sized using the 600 Cv rating.
   a. Maximum pressure drop shall not exceed 5-psig at design flow rate.
4. Flow Characteristics: Modified equal percentage, unidirectional dead-end service.
5. Close-Off Pressure Rating: Bubble-tight shutoff (no leakage).

6. The combination of two 2-way butterfly valves in a tee configuration cross-linked to ensure proper flow orientation shall be permitted. The tee shall be constructed of cast iron/stainless steel.

F. Hydronic system Butterfly Valves - High Performance shall have the following characteristics:
1. Valve body shall be full lugged carbon steel ANSI Class 150 body with a 316 stainless steel disc without a nylon coating, RTFE seat, and be ANSI Class 150300 flange standards. Blowout-proof shaft shall be 17-4ph stainless steel and shall be supported at four locations by glass-backed TFE bushings. Valve packing shall be Chevron TFE and shall include fully adjustable packing flange and separable packing gland. Valve body shall have long stem design to allow for 2 insulation (minimum). Valve face-to-face dimensions shall comply with API 609 and MSS-SP-68. Valve assembly shall be completely assembled and tested, ready for installation.
2. Sizing: Two-Position (on/off) butterfly valves shall be sized using the 900 Cv rating. Modulating butterfly valves shall be sized using the 600 Cv rating.
   a. Maximum pressure drop shall not exceed 5-psig at design flow rate.
3. Flow Characteristics: Modified equal percentage, full rated, bi-directional, dead-end service with either flange removed.
4. Close-Off Pressure Rating: Bubble-tight shutoff (no leakage).
5. Media Temperature Range: ANSI Class 150 limitations.
6. Max Differential Pressure: 285 psi @ 100 deg F for ANSI 150.
7. The combination of two 2-way butterfly valves in a tee configuration cross-linked to ensure proper flow orientation shall be permitted. The tee should be constructed of cast iron/stainless steel.

G. Bypass and Injection Control Valves
1. Approved Manufacturer: Valve shall be VSI Series V - High Performance Segmented Ball Valve equipped with a Series 1000-X Electric Actuator. No substitutions permitted.
2. Valve Construction:
   a. Close-Off Pressure Rating: Up to 250 psi for valves 1-6”, and 285 psi for valves 8-12”.
   b. Operating Temperature Range: -20°F to 400°F.
   c. Body: carbon steel or stainless steel.
   d. Ball: 304 stainless steel.
   e. Shaft: 304 stainless steel.
   f. Seat: TFM 1700
   g. Sealing components shall include ALFAS O-rings.
3. Sizing: Valves shall be sized to ensure a pressure drop between 3 psi and 6 psi at the design flow rate, unless otherwise noted on the drawings.
4. Flow Characteristic: Equal percentage.
5. Valve Actuator: Actuators shall be of the quarter turn type with a compact low-profile design to minimize space requirements. Valve actuators shall be digitally configurable and compatible with the valve for seamless integration and control. Valve actuators shall provide a minimum resolution of 200 discrete steps to ensure high-precision modulation and stable control performance.

2.27 DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Air Balance Inc.
   2. TAMCO (T. A. Morrison & Co. Inc.).
   3. Vent Products Company, Inc.

B. Dampers: AMCA-rated, opposed-blade design; 0.108-inch-minimum thick, galvanized-steel or 0.125-inch- minimum thick, extruded-aluminum frames with holes for duct mounting; damper blades shall not be less than 0.064-inch- thick galvanized steel with maximum blade width of 8 inches and length of 48 inches.
   1. Secure blades to 1/2-inch- diameter, zinc-plated axles using zinc-plated hardware, with oil-impregnated sintered bronze blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.
   2. Operating Temperature Range: From minus 40 to plus 200 deg F.
   3. Edge Seals, Standard Pressure Applications: Closed-cell neoprene.
   4. Edge Seals, Low-Leakage Applications: Use inflatable blade edging or replaceable rubber blade seals and spring-loaded stainless-steel side seals, rated for leakage at less than 10 cfm per sq. ft. of damper area, at differential pressure of 4-inch wg when damper is held by torque of 50 in. x lbf; when tested according to AMCA 500D.

2.28 CONTROL WIRE AND CABLE

A. Wire: Single conductor control wiring above 24 V.
   1. Wire Size: Minimum 14 AWG.
   2. Conductors: 7/24 soft annealed copper strand with 2- to 2.5-inch lay.
   3. Conductor Insulation: 600 V, Type THWN or Type THHN, and 90 deg C in accordance with UL 83.
   4. Conductor Insulation Colors: Black (hot), white (neutral), and green (ground).
   5. Furnish on spools.

B. Single, Twisted-Shielded, Instrumentation Cable 24 V and Less:
   1. Wire Size: Minimum 18 AWG.
   2. Conductors: Twisted, 7/24 soft annealed copper stranding with a 2- to 2.5-inch lay.
   3. Conductor Insulation: Nominal 15-mil thickness, constructed from flame-retardant PVC.
   4. Conductor Insulation Colors:
      a. Twisted Pair: Black and white.
      b. Twisted Triad: Black, red, and white.
   5. Shielding: 100 percent type, 1.35-mil aluminum/polymer tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
   6. Outer Jacket Insulation: 300 V, 105 deg C rating, and Type PLTC cable.
   7. Furnish on spools.

C. LAN and Communication Cable: Comply with DDC system manufacturer requirements for network being installed.

1. Electronic and fiber-optic cables for control wiring are specified in Section 271500 "Communications Horizontal Cabling."
   a. Plenum rated.
   b. Unique color that is different from other cables used on Project.

D. Serial Communication Cable: Comply with DDC system manufacturer requirements for network being installed.
   1. Plenum rated.
   2. Shielded twisted pair.
   3. Comply with any third-party manufacturer requirements that are more stringent than the DDC system manufacturer's requirements.

2.29 PRESSURE INSTRUMENT SIGNAL AIR PIPING AND TUBING

A. Products in this article are intended for use with the following:
   1. Main air and signal air to pneumatically controlled instruments, actuators, and other control devices and accessories.
   2. Signal air between pressure instruments, such as sensors, switches, transmitters, controllers, and accessories.

B. Copper Tubing:
   1. Seamless phosphor deoxidized copper, drawn tempered, with chemical and physical properties in accordance with ASTM B75/B75M.
   2. Performance, dimensions, weight, and tolerance in accordance with ASTM B280.
   3. Diameter, as required by application, not less than nominal 1/4 inch.
   4. Wall thickness, as required by application, but not less than 0.030 inch.
   5. Copper Tubing Connectors and Fittings - Brass, Compression Type:
      a. Single or double ferrule design creating a constant tension between fitting body and fitting nut for leak-free seal.
   6. Copper Tubing Connectors and Fittings - Copper, Solder-Joint Type:
      a. Copper Solder-Joint Fittings: Cast, ASME B16.18 or wrought, ASME B16.22.

C. Polyethylene Tubing: (For Pneumatic/Pressure Instrument Signal Air).
   1. Fire-resistant, black virgin polyethylene in accordance with ASTM D1248, Type 1, Class C, and Grade 5.
   2. Complying with stress crack test in accordance with ASTM D1693.
   3. Diameter, as required by application, of not less than nominal 1/4 inch.
   4. Polyethylene Tubing Connectors and Fittings - Brass, Barb Fittings:
      a. Tapered and beaded hose barbs of push-on design; intended for low-pressure applications only.
   5. Polyethylene Tubing Connectors and Fittings - Brass, Compression Type:
      a. Specially designed for jointing polyethylene tubing to provide leak-free seal without twisting or weakening polyethylene tubing.

2.30 IDENTIFICATION

A. Instrument Air Pipe and Tubing:
   1. Engraved tag bearing the following information:
      a. Service (Example): "Instrument Air."
      b. Pressure Range (Example): 0 to 30 psig.
   2. Letter size minimum of 0.25 inch high.

3. Engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers color-coded blue with contrasting white center exposed by engraving through outer layer.
4. Include tag with brass grommet, chain, and S-hook.

B. Control Equipment, Instruments, and Control Devices:
1. Self-adhesive label bearing unique identification.
   a. Include instruments with unique identification identified by equipment being controlled or monitored, followed by point identification.
2. Letter size as follows:
   a. Servers: Minimum of 0.5 inch high.
   b. DDC Controllers: Minimum of 0.5 inch high.
   c. Gateways: Minimum of 0.5 inch high.
   d. Repeaters: Minimum of 0.5 inch high.
   e. Enclosures: Minimum of 0.5 inch high.
   f. Electrical Power Devices: Minimum of 0.25 inch high.
   g. UPS units: Minimum of 0.5 inch high.
   h. Accessories: Minimum of 0.25 inch high.
   i. Instruments: Minimum of 0.25 inch high.
   j. Control Damper and Valve Actuators: Minimum of 0.25 inch high.
   k. Engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers color-coded black with contrasting white center exposed by engraving through outer layer.
   l. Fastened with drive pins.
   m. Instruments, control devices, and actuators with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require additional identification.

C. Valve Tags:
1. Brass tags and brass chains attached to valve.
2. Tag Size: Minimum 1.5 inches in diameter.
3. Include tag with unique valve identification indicating control influence such as flow, level, pressure, or temperature; followed by location of valve and followed by three-digit sequential number. For example: TV-1.001.
4. Valves with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require an additional tag.

D. Raceway and Boxes:
1. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
2. Paint cover plates on junction boxes and conduit same color as tape banding for conduits. After painting, label cover plate "HVAC Controls".
3. For raceways housing pneumatic tubing, add phenolic tag labeled "HVAC Instrument Air Tubing."
4. For raceways housing air signal tubing, add phenolic tag labeled "HVAC Air Signal Tubing."

E. Equipment Warning Labels:

1. Self-adhesive label with pressure-sensitive adhesive back and peel-off protective jacket.
2. Lettering size at least 14-point type with white lettering on red background.
3. Warning label to read "CAUTION-Equipment operated under remote automatic control and may start or stop at any time without warning. Switch electric power disconnecting means to OFF position before servicing."
4. Lettering to be enclosed in a white line border. Edge of label is to extend at least 0.25 inch beyond white border.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verify that conditioned power supply is available to control units and operator workstation.

B. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
   1. Verify compatibility with and suitability of substrates.

C. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.

D. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.

E. Examine walls, floors, roofs, and ceilings for suitable conditions where product will be installed.

F. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.

G. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 GENERAL

A. All control system components shall be installed in locations as required to properly sense the controlled medium.

B. BAS Installation shall be performed by professionals in a workmanlike manner and in compliance with the Contract Documents, Division 26 Project Electrical System Specifications, the National Electric Code (NEC), and any/all applicable local codes and/or Authorities Having Jurisdiction (AHJ) and the following:
   1. Complete BAS installation including all DDC Devices, Enclosures, wiring, equipment, control devices and sensors shall be installed in accordance with the manufacturer’s recommended installation procedures and as specified.
   2. All flow stations (air and water) shall be installed according to the manufacturer’s installation guidelines. This includes but is not limited to installation location, device orientation, flow direction, up/downstream distances from disturbances, and straight run requirements.

3. All control devices are to be provided and installed with all required gaskets, seals, flanges, connection enclosures, thermal compounds, insulation, piping, fittings and valves as required for design operation, isolation, equalization, purging and calibration.
4. Strap-on control devices shall not be permitted except as explicitly called out.
5. All control devices mounted outdoors shall be protected by a weather-shield, integral outdoor enclosure, from ambient elements in such a manner as to not impede design functionality and/or sensing.
6. BAS installation shall be such that it provides sufficient clearance for system maintenance by maintaining sufficient access for equipment, device and/or component service, calibration, removal, repair or replacement.
7. BAS installation shall not interfere with required clearance for mechanical and/or electrical equipment maintenance.
8. Penetrations through and mounting holes in the building exterior associated with the BAS installation shall be sealed and made watertight.
9. Dielectric isolation shall be provided where dissimilar metals are used in installation for connection and support.

C. Installation, wiring and material shall be protected from damage or theft before, during, and after installation. Any damaged or stolen installation, wiring, or material shall be repaired or replaced.

D. After completion of installation, calibrate and commission all components provided as part of the Control System and demonstrate proper sequence of operation in compliance with the specifications. BAS components not operating correctly shall be field corrected or replaced.

3.3 BAS APPLICATION SOFTWARE

A. At time of acceptance all operating system, Third party and Control System Application software shall be at least the latest official release version available.

B. Software programs are described to their general intent. It is recognized that Networked System manufacturer's software differ; however, the Application software provided shall incorporate the features described fully implemented and optimized to provide the sequences described, minimize energy consumption and prolong equipment life.

C. When programming the system BACnet addressing rules will be strictly adhered to. All addressing strategies will have to be approved by Owner and Engineer of Record prior to configuring any LAN types.

D. All analog and binary values shall be programmed with appropriate alarms.

E. Except as specified otherwise, throttling ranges, proportional bands, and switching differentials shall be centered on the associated set point.

F. All set points unless otherwise indicated are adjustable and shall be programmable for all control loops.

G. Each control loop and/or interlock(s) for all mechanical system including terminal unit systems shall be programmed with a control loop specific graphical trend to trend all values associated with each specific control loop or system interlock.

H. Where any sequence or occupancy schedule calls for more than one motorized unit to start simultaneously, the system start commands shall be staggered by 15-second (adj.) intervals to minimize inrush current.

I. Scheduling shall be developed for each mechanical system. Final schedules shall be coordinated with the Owner and Engineer of Record prior to system commissioning.

J. Optimal start/stop programs shall be applied to all regularly scheduled mechanical and electrical systems.

K. At a minimum, trend log/historical data shall be implemented for every hardware point on the system. Additionally all software (virtual) points used as setpoints shall be trended. Point trends shall be grouped into logically interrelated points for individual mechanical and building systems. Initial set-up shall be to log values once every 5 minutes.

L. B-AWS Graphical User Interface (GUI) must be approved by the Owner and Engineer of Record and shall incorporate at a minimum the following:
   1. At a minimum, all physical hardware, sensors, control devices and set points shall be visible on a B-AWS in graphical form.
   2. All mechanical systems shall have a programmed real time color graphic for primary graphical user interface.
   3. Individual floor plan graphics will be programmed for each floor or area of the building. All space sensors shall be visible on floor plan graphics and system graphic.

3.4 B-AWS HARDWARE

A. Provide as specified for each PC-Based B-AWS.

B. Assemble server components in a configuration that allows easy operator access to all necessary components from one position.

C. Provide sufficient permanent and removable storage drives for 25% free memory after provision for all operating system, Third party and Control System Application software, all fully configured point databases, storage/back-up of all B-BC, B-AAC and B-ASC application programming, all graphic files, all user-defined reports and a three year archive of all trend and historical data described in this specification.

D. Provide sufficient RAM to meet system performance requirements.

3.5 BACnet PROTOCOL VERIFICATION SOFTWARE

A. Demonstrate exclusive communication utilizing the BACnet Protocol on all segments of the BACnet network.

3.6 BUILDING CONTROLLER (B-BC)

A. Provide as required to meet performance requirements of the system with a 10% increase in connected B-AAC and B-ASC on any individual network. Provide a dedicated B-BC for all project specific equipment requiring this controller type.

B. Locate strategically such that B-BC locations are as equally distributed throughout the project as possible.

C. All points used for a single mechanical system shall be connected to the same B-BC. Points used for control loop reset based on outside air, or space/zone temperature, or extremely remote differential pressure sensors on slow acting control loops are exempt from this requirement.

D. Provide spare additional I/O such that future use of spare capacity shall require providing only the field device, field wiring, point database definition and operational sequence programming changes as required. Additional point modules may be required to implement use of these spare points.
   1. Controllers shall be selected to provide a minimum of 15% spare I/O point capacity for each point type found at each location. If input points are not universal, 15% of each type is required. If outputs are not universal, 15% of each type is required. A minimum of one spare is required for each type of point used.

3.7 ADVANCED APPLICATION CONTROLLERS (B-AAC)

A. Provide a dedicated B-AAC for each medium-sized mechanical system.

B. All points used for a single mechanical system shall be connected to the same B-AAC. Points used for control loop reset based on outside air, or space/zone temperature, or extremely remote differential pressure sensors on slow acting control loops are exempt from this requirement.

C. Provide spare additional I/O such that future use of spare capacity shall require providing only the field device, field wiring, point database definition and operational sequence programming changes as required. Additional point modules may be required to implement use of these spare points.
   1. Controllers shall be selected to provide a minimum of 15% spare I/O point capacity for each point type found at each location. If input points are not universal, 15% of each type is required. If outputs are not universal, 15% of each type is required. A minimum of one spare is required for each type of point used.
   2.

3.8 APPLICATION SPECIFIC CONTROLLERS (B-ASC)

A. Provide a dedicated B-ASC for each Terminal Unit Mechanical Device on the project, including VAV and Fan Powered Terminal Units, Unit Heaters, and Individual Fans.

B. All points used for a single Terminal Unit Mechanical Device shall be connected to a dedicated B-ASC. Points used for control loop reset based on outside air, or space/zone temperature, or extremely remote differential pressure sensors on slow acting control loops are exempt from this requirement.

C. Provide spare additional I/O such that future use of spare capacity shall require providing only the field device, field wiring, point database definition and operational sequence programming changes as required. Additional point modules may be required to implement use of these spare points.
   1. Controllers shall be selected to provide a minimum of 15% spare I/O point capacity for each point type found at each location. If input points are not universal, 15% of each type is required. If outputs are not universal, 15% of each type is required. A minimum of one spare is required for each type of point used.

D. VAV ATU and FP-VAV ATU Controllers

1. Provide networked B-ASC for each VAV ATU and FP-VAV ATU consisting of a controller, damper actuator, and velocity transducer.
2. The ATU shall be provided with multi-point averaging type flow sensor factory piped to the velocity transducer.

3.9 LOCAL SYSTEM NETWORK INTERFACE

A. At a minimum the Portable B-AWS shall be able to connect to the BACnet Internetwork within each mechanical equipment space within the project.

3.10 ENCLOSURES & SUB-PANELS

A. All system components not designed for or required to be field installed shall be mounted in a control enclosure. Those components shall be sub panel mounted except components that are mounted on the panel face. Provide on/off power switch with over-current protection for control power sources in each local enclosure.

B. All control enclosures shall be located so that visual observation and adjustment can be accomplished while standing flatfooted on the floor in a convenient location adjacent to the equipment served. Install all equipment in readily accessible location as defined by Chapter1 Article 100 Part A of the NEC.

C. Label all control system components.

D. A copy of the ÓAs-built application engineering for the system served shall be laminated in clear plastic, shall be legible and suspended within enclosure.

E. All B-BC shall be mounted in an enclosure.

3.11 INSTALLATION

A. Install software in control units and operator workstation(s). Implement all features of programs to specified requirements and as appropriate to sequence of operation.

B. Connect and configure equipment and software to achieve sequence of operation specified.

C. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices 48 inches above the floor.
   1. Install averaging elements in ducts and plenums in crossing or zigzag pattern.

D. Install guards on thermostats in the following locations:

   1. Entrances.
   2. Public areas.
   3. Where indicated.

E. Install automatic dampers according to Section 233300 "Air Duct Accessories."

F. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.

G. Install labels and nameplates to identify control components according to Section 230553 "Identification for HVAC Piping and Equipment."

H. Install hydronic instrument wells, valves, and other accessories according to Section 232116 Hydronic Piping Specialties."

I. Install steam and condensate instrument wells, valves, and other accessories according to Section 232216 Steam and Condensate Piping Specialties."

J. Install refrigerant instrument wells, valves, and other accessories according to Section 232300 "Refrigerant Piping."

K. Install duct volume-control dampers according to Section 233113 "Metal Ducts" and Section 233116 "Nonmetal Ducts."

L. Install electronic and fiber-optic cables according to Section 271500 "Communications Horizontal Cabling."

3.12 ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. General
   1. Provide all wiring required for a complete Control System.
   2. Control system wiring and cabling installed for this project shall be performed by professionals in a workmanlike manner and in accordance with the Contract Documents, Division 26 Project Electrical System Specifications, the National Electric Code (NEC), and any/all applicable local codes and/or Authorities Having Jurisdiction (AHJ) and shall include but may not be limited to the following:
      a. All power wiring required not indicated on the electrical plans and specifications.
      b. Power to all actuators and sensors.
      c. Provide all wiring and cabling for network communications except for owner provided LANs/WANs.
      d. All sensor and control device input and output wiring.
      e. All interconnecting cabling between and amongst network devices, PCs printers, etc.
      f. Interlock wiring between devices, variable frequency drives and between motor starters.
      g. All other necessary wiring for fully complete and functional system as specified.
      h. Install piping, wiring/cabling routed parallel to or at right angles with the structure, properly supported every six (6) feet at a minimum and installed in a workmanlike manner.
   3. Maximum allowable voltage for control wiring shall be 120-volts.
   4. All wiring shall be installed as continuous links. Any required splices shall be made only within an approved junction box or other approved protective device with a maximum fill of 50%.
      a. BACnet network cabling shall not be field spliced.
   5. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.
   6. Terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.

B. Power Wiring and Cabling
   1. Obtain power and provide wiring for all enclosures and controls equipment, including branch circuit wiring from circuit breaker panels unless specifically shown on the Plans or Specifications to be provided under Division 26.
   2. All B-AWS equipment shall be served from isolated ground receptacles via UPS by dedicated branch circuits.

3. All other enclosures, sensor and control devices shall be fed from separate circuits in the electrical distribution panels and shall not be served from the typical floor receptacle or lighting circuits.

C. Network Wiring and Cabling
1. Network installation shall strictly adhere to the manufacturer's networking installation instructions and procedures.
2. Network installation shall conform to standards for the LAN types and cabling types selected. Specific network rules inherent to the ANSI/AHRAE Standard 135-2016, BACnet shall be followed. Those include but are not limited to:
   a. Only one path can exist from any BACnet device to another.
   b. Each BACnet device connected to an internetwork LAN must have a unique device instance (0 - 4,194,303).
   c. Each internetwork LAN must have a unique Network Number (1 - 65,545).
3. Primary LAN Network wire and cable shall be run separately from all other wiring.
4. Other LAN Network wire and cabling shall be installed separate from any wiring over thirty (30) volts.
5. All communications shielding shall be grounded as per Networked System manufacturer’s recommendations.

D. Installation
1. Install raceways, boxes, and cabinets according to Section 260533 "Raceways and Boxes for Electrical Systems."
2. Install building wire and cable according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
3. Install signal and communication cable according to Section 271500 "Communications Horizontal Cabling."
   a. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
   b. Install exposed cable in raceway.
   c. Install concealed cable in raceway.
   d. Bundle and harness multiconductor instrument cable in place of single cables where several cables follow a common path.
   e. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
   f. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.
   g. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.
4. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.
5. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

3.13 INSTALLATION OF SENSORS

A. Temperature
1. All wires attached to sensors shall be air sealed in their conduits or in the wall to stop air transmitted from other areas affecting sensor readings.

2. Install and properly support all enclosures and sensing elements as much as possible in the center of duct cross section and in straight duct runs. In condensing environments use stainless steel flanges to support sensing elements.
3. Sensors mounted on air ducts having exterior insulation shall be provided with handy-box mounting with insulating material firmly fitted around handy-box.
4. Averaging type sensors: provide a minimum of 1 linear foot of sensor per 4 square feet of duct/coil area or equal to duct/coil width where installed, whichever is longer. Averaging sensing tubing shall serpentine vertically across airstream and be supported firmly by mechanical clips.
5. Low-limit sensors used in mixing plenums shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip. Provide 3 m (10 ft) of sensing element for each 1 m2 (1 ft of sensing element for each 1 ft2) of coil area.
6. Temperature sensors installed in piping or tanks shall be in separable thermowells. Sensors shall be inserted into thermowells with conductive paste. Assembly shall allow removal of sensor without loss of fluid.
7. At a minimum one outside air temperature sensor shall be installed. It shall be mounted outside on a northern exposure as high as serviceable on the building. The sensor shall be mounted within a ventilated enclosure to shield the sensor from the effects of the sun. The sensor location shall be selected such that it may not be affected by artificial and/or mechanical airstreams (i.e., building exhaust, building relief, etc.).
8. Terminal Unit Sensors shall be provided one per terminal unit device.
   a. They shall be wall mounted in the space served 60 inches above finished floor and located as shown on drawings.
   b. Provide a minimum of 16 feet of coiled temperature sensor control wiring for equipment with space sensor not located on the Drawings.
9. In all areas where terminal unit sensor locations are not known at the time of building startup, sensors shall be hung approximately 24 inches from the ceiling in the area of the controlled zone and connected. Control wiring shall be neatly coiled and attached to ceiling grid.
10. Zone temperature sensors shall not be located on perimeter walls. Where explicitly indicated on drawings to do so and/or in locations near exterior walls and/or subject to drafts sensors shall have insulated mounting bases to prevent false room temperature readings.
11. Where wall sensors are mounted in an area subject to damage provide suitable protective guard.
12. Where wall sensors are mounted in public spaces with adjustable set points provide suitable security guard.

B. Wet Bulb
   1. For outside air mount same as outside air temperature sensor.
   2. For duct mounting execute same as duct mounted temperature sensor.

C. Pressure
   1. Orient static pressure sensing taps faced directly down-stream in the airflow so as to eliminate velocity pressure effects. Locate pressure transducers within 10 feet of sensing point and use tubing sized such as to prevent signal phase lag.

a. Final location of static/differential pressure sensing taps shall be pursuant with Contract Documents and as indicated on drawings. Where not explicitly indicated on drawings, pressure sensing taps shall be located as follows:
   1) Duct static pressure control sensor tap shall be located 2/3 distance from the Air Handling Unit of the total duct length in a straight section of ductwork with a minimum or four (4) duct diameters in both directions.
   2) Positive static high-pressure safety cut-outs shall be located at Air Handling Unit immediately downstream of fan section.
   3) Mixed-Air static and/or differential sensor tap shall be located in mixing box section.
   4) Negative static pressure safety cut-outs shall be located immediately upstream of fan section.
   5) Filter differential pressure taps shall be installed on both filter inlet and outlet.
   6) Building Static Pressure. Pipe the low-pressure port of the pressure sensor to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe the high-pressure port to a location behind a thermostat cover.
   7) The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.
   8) All pressure transducers, other than those controlling VAV boxes, shall be located in field device panels, not on the equipment monitored or on ductwork. Mount transducers in a location accessible for service without use of ladders or special equipment.

b. Mount air differential pressure taps so that true differential is sensed.

2. Water gauge taps shall include snubbers and isolation valves.
3. Water differential pressure sensors shall be piped through a five-valve bypass assembly with snubbers.

3.14 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:
   1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
   2. Test and adjust controls and safeties.
   3. Test calibration of electronic controllers by disconnecting input sensors and stimulating operation with compatible signal generator.
   4. Test each system for compliance with sequence of operation.
   5. Test software and hardware interlocks.

C. DDC Verification:
   1. Verify that instruments are installed before calibration, testing, and loop or leak checks.

2. Check instruments for proper location and accessibility.
3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
4. Check instrument tubing for proper fittings, slope, material, and support.
5. Check installation of air supply for each instrument.
6. Check flow instruments. Inspect tag number and line and bore size and verify that inlet side is identified and that meters are installed correctly.
7. Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.
8. Check temperature instruments and material and length of sensing elements.
9. Check control valves. Verify that they are in correct direction.
10. Check DDC system as follows:
    a. Verify that DDC controller power supply is from emergency power supply, if applicable.
    b. Verify that wires at control panels are tagged with their service designation and approved tagging system.
    c. Verify that spare I/O capacity has been provided.
    d. Verify that DDC controllers are protected from power supply surges.

D. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

3.15 PROGRAMMING

A. Provide sufficient internal memory for the specified sequences of operation and trend logging. There shall be a minimum of 25% of available memory free for future use.

B. Point Naming. System point names shall be modular in design, allowing easy operator interface without the use of a written point index.

C. Use device identification that is consistent with the established naming conventions at the place of work. Coordinate identification of equipment and systems supplied by other divisions to ensure that identical naming conventions are used.

D. The BAS device network shall support up to a 32-character object name consisting only of ASCII printable characters. The convention to be used for all object names is as follows:
1. Object name format shall be in the form of “xyz#-aaaaaa-nnn-aaaaaaaaaaaaa,” where “a” designates an alphanumeric character and “n” is a digit from 0 to 9. The underscore character is not allowed so that all names are compliant with domain naming conventions.
2. The next three digits, “xyz#” followed by a dash “-”, designate a building identifier number. If fewer than three digits are used, the front of the building number must be padded with leading zeros.
3. The next six alphanumeric characters, “aaaaa” followed by a dash “-”, designate the equipment or system name. No spaces are allowed in the equipment/system name; however, the name length may be shortened as required to no fewer than three alphanumeric characters.
4. The three digits “nnn” followed by a dash “-” designate the system number. If fewer than three digits are used, the front of the system number must be padded with leading zeros.

5. The final thirteen alphanumeric characters, “aaaaaaaaaaaaa,” designate the device or sensor connected to that system. No spaces are allowed in the device/sensor name; however, the name length may be shortened as required to no fewer than six alphanumeric characters.

E. This naming convention applies to all objects provided by this contractor as well as to all objects that are mapped from the BACnet devices provided by others in the work.

F. If the contractor’s panel does not support a maximum 32-character object name, map all objects to a BAS panel that supports this requirement.

G. Software Programming
1. Provide programming for the system and adhere to the sequences of operation provided. All other system programming necessary for the operation of the system, but not specified in this document, also shall be provided by the contractor. Embed 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. Use the appropriate technique based on the following programming types:
2. Text-based
   a. Must provide actions for all possible situations.
   b. Must be modular and structured.
   c. Must be commented.
3. Graphic-based
   a. Must provide actions for all possible situations.
   b. Must be documented.
4. Parameter-based
   a. Must provide actions for all possible situations.
   b. Must be documented.
5. Submit sample programming of representative systems for approval by BAS designer.

H. Operator Interface
1. Standard graphics—provide graphics for all mechanical systems and floor plans of the building. This includes each chilled-water system, hot-water system, chiller, boiler, air handler, and all terminal equipment. Point information on the graphic displays shall dynamically update. Show on each graphic all input and output points for the system. Also show relevant calculated points, such as set points.
2. Submit sample graphic page layouts for approval by BAS designer.
3. Show terminal equipment information on a graphic summary table. Provide dynamic information for each point shown.
4. The contractor shall provide all the labor necessary to install, initialize, start up, and trouble- shoot all operator interface software and its functions as described in this section. This includes any operating system software, the operator interface database, and any third- party software installation and integration required for successful operation of the operator interface.

3.16 CALIBRATION, COMMISSIONING. DEMONSTRATION AND ACCEPTANCE

A. Commissioning, Calibrating and Adjusting:

1. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Controls Components," in the absence of specific requirements, and to supplement requirements indicated. Confirm in writing to the Owner and Architect the compliance with the field-testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Controls Components".
2. Pretest Checklist and Test Plan
   a. Perform validation tests before requesting final review of system. Before beginning testing, first submit Pretest Checklist and Test Plan.
   b. After approval by Owner or Architect of the Pretest Checklist and Test Plan, execute all tests and procedures indicated in plan.
   c. After testing is complete, submit completed Pretest Checklist.
   d. Pretest Checklist: Submit the following list with items checked off once verified:
      1) Detailed explanation for any items that are not completed or verified.
      2) Required mechanical installation work is successfully completed and HVAC equipment is working correctly.
      3) HVAC equipment motors operate below full-load amperage ratings.
      4) Required DDC system components, wiring, and accessories are installed.
      5) Installed DDC system architecture matches approved Drawings.
      6) Control electric power circuits operate at proper voltage and are free from faults.
      7) Required surge protection is installed.
      8) DDC system network communications function properly, including uploading and downloading programming changes.
      9) Using BACnet protocol analyzer, verify that communications are error free.
      10) Each controller's programming is backed up.
      11) Equipment, products, tubing, wiring cable, and conduits are properly labeled.
      12) All I/O points are programmed into controllers.
      13) Testing, adjusting, and balancing work affecting controls is complete.
      14) Dampers and actuators zero and span adjustments are set properly.
      15) Each control damper and actuator goes to failed position on loss of power and loss of signal.
      16) Valves and actuators zero and span adjustments are set properly.
      17) Each control valve and actuator goes to failed position on loss of power and loss of signal.
      18) Meter, sensor, and transmitter readings are accurate and calibrated.
      19) Control loops are tuned for smooth and stable operation.
      20) View trend data where applicable.
      21) Each controller works properly in standalone mode.
      22) Safety controls and devices function properly.
      23) Interfaces with fire-alarm system function properly.
      24) Electrical interlocks function properly.
      25) Operator workstations and other interfaces are delivered, all system and database software is installed, and graphics are created.
      26) Record Drawings are completed.

e. Test Plan:
   1) Prepare and submit validation Test Plan including test procedures for performance validation tests.
   2) Address all specified functions of DDC system and sequences of operation in Test Plan.
   3) Explain detailed actions and expected results to demonstrate compliance with requirements indicated.
   4) Explain method for simulating necessary conditions of operation used to demonstrate performance.
   5) Include Test Checklist to be used to check and initial that each test has been successfully completed.
   6) Submit Test Plan documentation twenty business days before start of tests.

3. Fully commission the entire BAS. All commissioning shall be fully documented, and all documentation shall be submitted prior to Demonstration and Acceptance testing.
   a. Commissioning shall include a point-to-point check-out of all I/O points in the DDC system.
   b. Verify that all Temperature Control Panels (TCP), BAS equipment, controllers, devices and sensors are installed and operational according to the specifications, submittals and manufacturer¢¢s installation and application instructions.
   c. Calibrate all inputs by comparing the actual site condition with the B-AWS point display.
   d. Verify all outputs from B-AWS command to observed response of controlled device.
   e. Verify failure response and fail-safe conditions of all devices and safeties.
   f. Each control program shall be fully commissioned and tested for complete design intent compliance and functionality.
      1) Adjust control loop proportional, integral, and derivative settings to achieve optimum performance while complying with performance requirements indicated. Document testing of each control loop's precision and stability via trend logs.
   g. Verify overall network performance of BAS for complete design intent compliance and functionality with all devices on-line, communicating and fully operational.
   h. Subsystems not directly controlled by the BAS but associated with the ATC shall also be fully tested and commissioned as to design intent compliance and functionality.
   i. Validation Test:
      1) Verify operating performance of each I/O point in DDC system.
         a) Verify analog I/O points at operating value.
         b) Make adjustments to out-of-tolerance I/O points.
         c) Identify I/O points for future reference.
         d) Simulate abnormal conditions to demonstrate proper function of safety devices.
         e) Replace instruments and controllers that cannot maintain performance indicated after adjustments.
      2) Simulate conditions to demonstrate proper sequence of control.

3) Readjust settings to design values and observe ability of DDC system to establish desired conditions.
4) 24 hours after initial validation test, do as follows:
   a) Re-check I/O points that required corrections during initial test.
   b) Identify I/O points that still require additional correction and make corrections necessary to achieve desired results.
5) 24 Hours after second validation test, do as follows:
   a) Re-check I/O points that required corrections during second test.
   b) Continue validation testing until I/O point is normal on two consecutive tests.
6) Completely check out, calibrate, and test all connected hardware and software to ensure that DDC system performs according to requirements indicated.
7) After validation testing is complete, prepare and submit report indicating results of testing. For all I/O points that required correction, indicate how many validation re-tests it took to pass. Identify adjustments made for each test and indicate instruments that were replaced.

j. DDC System Response Time Test:
1) Simulate HLC.
   a) Heavy load to be occurrence of 50 percent of total connected binary COV, one-half of which represents "alarm" condition, and 50 percent of total connected analog COV, one-half of which represents "alarm" condition, that are initiated simultaneously on a one-time basis.
2) Initiate 10 successive occurrences of HLC and measure response time to typical alarms and status changes.
3) Measure with timer having at least 0.1-second resolution and 0.01 percent accuracy.
4) Purpose of test is to demonstrate DDC system, as follows:
   a) Reaction to COV and alarm conditions during HLC.
   b) Ability to update DDC system database during HLC.
5) Passing test is contingent on the following:
   a) Alarm reporting at printer beginning no more than two seconds after initiation (time zero) of HLC.
   b) All alarms, both binary and analog, are reported and printed; none are lost.
   c) Compliance with response times specified.
6) Prepare and submit report documenting HLC tested and results of test including time stamp and print out of all alarms.

k. DDC System Network Bandwidth Test:
1) Test network bandwidth usage on all DDC system networks to demonstrate bandwidth usage under DDC system normal operating conditions and under simulated HLC.
2) To pass, none of DDC system networks are to use more than 70 percent of available bandwidth under normal and HLC operation.

4. Calibrate instruments.

a. Make three-point calibration test for both linearity and accuracy for each analog instrument.

5. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
6. Control System Inputs and Outputs:
   a. Check analog inputs at 0, 50, and 100 percent of span.
   b. Check analog outputs using milliampere meter at 0, 50, and 100 percent output.
   c. Check digital inputs using jumper wire.
   d. Check digital outputs using ohmmeter to test for contact making or breaking.
   e. Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.
7. Flow:
   a. Set differential pressure flow transmitters for 0 and 100 percent values with 3-point calibration accomplished at 50, 90, and 100 percent of span.
   b. Manually operate flow switches to verify that they make or break contact.
8. Pressure:
   a. Calibrate pressure transmitters at 0, 50, and 100 percent of span.
   b. Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.
9. Temperature:
   a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
   b. Calibrate temperature switches to make or break contacts.
10. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.
11. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
12. Provide diagnostic and test instruments for calibration and adjustment of system.
13. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating startup procedures.

B. Adjust initial temperature and humidity set points.

C. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to three visits to Project during other than normal occupancy hours for this purpose.

D. Demonstration and Acceptance

1. Demonstrate compliance of the BAS with the contract documents and operational functionality pursuant with the design Sequences of Operation. Using the documented calibration and commissioning test data the Owner and/or its representative shall select, at random, results to be demonstrated. At least 95% of the results demonstrated must perform as specified and documented on commissioning data sheets or the system must be re-calibrated and re-commissioned before being re-tested.
2. When the Calibration, Commissioning, Demonstration and Acceptance process has been completed and approved by Owner, obtain signed letter from Owner indicating Acceptance within thirty (30) days of approval.

3.17 CONTROL VALVE INSTALLATION

A. Valve submittals shall be coordinated for type, quantity, size, and piping configuration to ensure compatibility with pipe design.

B. Slip-stem control valves shall be installed so that the stem position is not more than 60 degrees from the vertical up position. Ball-type control valves shall be installed with the stem in the horizontal position.

C. Valves shall be installed in accordance with the manufacturer's recommendations.

D. Control valves shall be installed so that they are accessible and serviceable and so that actuators may be serviced and removed without interference from structure or other pipes and/or equipment.

E. Isolation valves shall be installed so that the control-valve body may be serviced without draining the supply/return-side piping system. Unions shall be installed at all connections to screw-type control valves.

F. Provide tags for all control valves indicating service and number. Tags shall be brass, 38 mm (1.5 in.) diameter with 6.4 mm (0.25 in.) high letters. Securely fasten with chain and hook. Match identification numbers as shown on approved controls shop drawings.

3.18 CONTROL DAMPER INSTALLATION

A. Damper submittals shall be coordinated for type, quantity, and size to ensure compatibility with sheet metal design.

B. Duct openings shall be free of any obstruction or irregularities that might interfere with blade or linkage rotation or actuator mounting. Duct openings shall measure 6.4 mm (0.25 in.) larger than damper dimensions and shall be square, straight, and level.

C. Individual damper sections, as well as entire multiple section assemblies, must be completely square and free from racking, twisting, or bending. Measure diagonally from upper corners to opposite lower corners of each damper section. Both dimensions must be within 0.3 cm (0.125 in.) of each other.

D. Follow the manufacturer's instructions for field installation of control dampers. Unless specifically designed for vertical blade application, dampers must be mounted with blade axis horizontal.

E. Install extended shaft or jackshaft according to manufacturer's instructions. (Typically, a sticker on the damper face shows recommended extended shaft location. Attach shaft on labeled side of damper to that blade.)

F. Damper blades, axles, and linkage must operate without binding. Before system operation, cycle damper after installation to ensure proper operation. On multiple section assemblies, all sections must open and close simultaneously.

G. Provide a visible and accessible indication of damper position on the drive shaft end.

H. Support ductwork in area of damper when required to prevent sagging due to damper weight.

I. After installation of low-leakage dampers with seals, caulk between frame and duct or opening to prevent leakage around perimeter of damper.

3.19 ACTUATORS

A. Mount and link control damper actuators according to manufacturer's instructions.

B. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5 degrees open position, manually close the damper, and then tighten the linkage.

C. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.

D. Provide all mounting hardware and linkages for actuator installation.

E. Electric/Electronic Actuators
   1. Dampers. Actuators shall be direct-mounted on damper shaft or jackshaft unless shown as a linkage installation. For low-leakage dampers with seals, the actuator shall be mounted with a minimum 5 degrees available for tightening the damper seals. Actuators shall be mounted following manufacturer's recommendations.
   2. Valves. Actuators shall be connected to valves with adapters approved by the actuator manufacturer. Actuators and adapters shall be mounted following the actuator manufacturer's recommendations.

F. Pneumatic Actuators
   1. Size pneumatic damper actuator to operate the related control damper(s) with sufficient reserve power to provide smooth modulating action or two-position action. Actuator also shall be sized for proper speed of response at the velocity and pressure conditions to which the control damper is subject.
   2. Pneumatic damper actuators shall produce sufficient torque to close off against the maximum system pressures encountered. Size the pneumatic damper actuator to close off against the fan shutoff pressure, as a minimum.
   3. Where two or more pneumatic damper actuators are installed for interrelated operation in unison, such as dampers used for mixing, provide the dampers with a positive pilot positioner. The positive pilot positioner shall be directly mounted to the pneumatic damper actuator and have pressure gages for supply input and output pressures.
   4. The total damper area operated by an actuator shall not exceed 80% of the manufacturer's maximum area rating. Provide at least one actuator for each damper section. Each damper actuator shall not power more than 2 m2 (20 ft2) of damper.
   5. Use line shafting or shaft couplings (jack shafting) in lieu of blade-to-blade linkages or shaft coupling when driving axially aligned damper sections.

3.20 CONTROL AIR AND IMPULSE TUBING

A. Main air tubing shall be sized by the contractor. Main air runs on a floor shall be looped rather than a series of straight air runs.

B. Vertical risers shall be ridged copper.

C. Sensor tubing shall be sized by the contractor. Locate sensors to minimize tubing runs at the expense of increased wiring distances.

D. Locate air dryer in discharge air line from expansion/receiver tank. Wall-mount dryer on rubber in shear mounts. Install pressure regulator downstream of dryer. Pipe automatic drains to nearest floor drain.

E. Use Type L copper tubing in mechanical rooms where subject to damage or temperatures in excess of 95°C (200°F), where adjacent to heating pipes passing through common sleeve, and where not readily accessible. In mechanical rooms, bundled plastic tubing with suitable junction boxes or single plastic tubing with tray or raceway may be used.

F. Mechanically attach tubing to supporting surfaces. Sleeve through concrete surfaces in minimum 3 cm (1 in.) sleeves, extended 15 cm (6 in.) above floors and 3 cm (1 in.) below bottom surface of slabs.

G. Purge tubing with dry, oil-free compressed air nitrogen (if approved by safety department) before connecting control instruments.

H. All control air piping shall be concealed except in equipment rooms or unfinished areas. Installation methods/materials are as follows:
   1. Concealed and inaccessible. Use flame-retardant (FR) plastic in metal raceway. Room thermostat drops in stud walls in areas with lay-in ceiling may be FR plastic tubing.
   2. Concealed and accessible tubing (including ceiling return air plenums) shall be air-conditioning and refrigeration field service (ACR) copper tubing or FR plastic tubing, subject to the following limitations:
      a. FR tubing shall be enclosed in metal raceway when required by local code.
      b. Quantity of FR tubing per plenum volume of plenum space shall not exceed manufacturer’s published data for Class 1 installation.
   3. (Exposed) Use hard-drawn ACR copper or FR plastic in metal raceway.

I. Where copper tubing is used, a section 0.5 m (18 in.) or less of FR plastic tubing is acceptable at final connection to control device.

J. Pneumatic tubing shall not be run in raceway containing electrical wiring.

K. Where FR tubing exits the end of raceway or junction box, provide snap-in nylon bushing. Where pneumatic tubing exits control panels, provide bulkhead fittings. Where copper tubing exits junction boxes or panels, provide bulkhead fittings.

L. All control air piping shall be installed in a neat and workmanlike manner parallel to building lines with adequate support.

M. Piping above suspended ceilings shall be supported from or anchored to structural members or other piping and/or duct supports. Tubing shall not be supported by or anchored to electrical raceways or ceiling support systems.

N. For air pressures greater than 200 kPa (30 psig), compression- or solder-type connection shall be used.

O. When FR plastic tubing is used for pressures 200 kPa (30 psig) or less, brass-barbed fittings may be used. Plastic fittings are not acceptable.

P. Brass-barbed fittings shall be used at copper-to-FR-tubing junctions. Plastic slipped-over copper tubing is not acceptable.

Q. Perform a pressure test on the entire pneumatic system as follows:
   1. Test high-pressure air piping at 1000 kPa (150 psig) air pressure. Maintain this pressure for two hours without loss of pressure. If loss of pressure is indicated, correct and retest until the system shows no loss of pressure for two hours.
   2. Test low-pressure air tubing at 200 kPa (30 psig) air pressure. Maintain this pressure for two hours without pumping, during which time the pressure shall not drop more than 7 kPa (1 psi). Should pressure loss occur, determine the leak, repair with new equipment or piping, and retest until the system shows no more than 7 kPa (1 psi) pressure drop in two hours.
   3. Leaks at pipe and tube joints shall be corrected by remaking of the joints.

3.21 CLEANING

A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.

B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.

C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.22 TRAINING

A. Refer to Section 017900 "Demonstration and Training."

B. Provide instruction on the adjustment, operation and maintenance of the BAS as installed including all hardware and software provided by a manufacturer-trained, competent application engineer and/or technician with sufficient experience in the installation, programming and operation of the BAS. Provide all training equipment and material.

C. Training Schedule:
   1. Schedule training with Owner 20 business days before expected Substantial Completion.
   2. Schedule training to provide Owner with at least 20 business days of notice in advance of training.
   3. Training to occur within normal business hours at mutually agreed on time. Unless otherwise agreed to, training to occur Monday through Friday, except on U.S. Federal holidays, with two morning sessions and two afternoon sessions. Each morning session and afternoon session to be split in half with 15 -minute break between sessions. Morning and afternoon sessions to be separated by 30 -minute lunch period. Training, including breaks and excluding lunch period, are not to exceed eight hours per day.

4. Provide staggered training schedule as requested by Owner.

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

E. Attendee Training Manuals:
1. Provide each attendee with color hard copy of all training materials and visual presentations.
2. Organize hard-copy materials in three-ring binder with table of contents and individual divider tabs marked for each logical grouping of subject matter. Organize material to provide space for attendees to take handwritten notes within training manuals.
3. In addition to hard-copy materials included in training manual, provide each binder with a sleeve or pocket that includes DVD or flash drive with PDF copy of all hard-copy materials.

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

G. Training Outline:
1. Submit training outline for Owner review at least ten business days before scheduling training.
2. Include in outline a detailed agenda for each training day that is broken down into each of four training sessions that day, training objectives for each training session, and synopses for each lesson planned.

H. On-Site Training:
1. Owner will provide conditioned classroom or workspace with ample desks or tables, chairs, power, and data connectivity for instructor and each attendee.
2. Provide training materials, projector, and other audiovisual equipment used in training.

3. Provide as much of training located on-site as deemed feasible and practical by Owner.
4. Include on-site training with regular walk-through tours, as required, to observe each unique product type installed with hands-on review of operation, calibration, and service requirements.
5. Use operator workstation that is to be used with DDC system in the training. If operator workstations are unavailable, provide temporary workstation to convey training content.

I. Training Content for Daily Operators:
1. Basic operation of system.
2. Understanding DDC system architecture and configuration.
3. Understanding each unique product type installed including performance and service requirements for each.
4. Understanding operation of each system and equipment controlled by DDC system including sequences of operation, each unique control algorithm, and each unique optimization routine.
5. Operating operator workstations, printers, and other peripherals.
6. Logging on and off system.
7. Accessing graphics, reports, and alarms.
8. Adjusting and changing set points and time schedules.
9. Recognizing DDC system malfunctions.
10. Understanding content of operation and maintenance manuals including control drawings.
11. Understanding physical location and placement of DDC controllers and I/O hardware.
12. Accessing data from DDC controllers.
13. Operating portable operator workstations.
14. Review of DDC testing results to establish basic understanding of DDC system operating performance and HVAC system limitations as of Substantial Completion.
15. Running each specified report and log.
16. Displaying and demonstrating each data entry to show Project-specific customizing capability. Demonstrating parameter changes.
17. Stepping through graphics penetration tree, displaying all graphics, demonstrating dynamic updating, and direct access to graphics.
18. Executing digital and analog commands in graphic mode.
19. Demonstrating control loop precision and stability via trend logs of I/O for not less than 10 percent of I/O installed.
20. Demonstrating DDC system performance through trend logs and command tracing.
21. Demonstrating scan, update, and alarm responsiveness.
22. Demonstrating spreadsheet and curve plot software, and its integration with database.
23. Demonstrating on-line user guide and help function and mail facility.
24. Demonstrating multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
25. Demonstrating the following for HVAC systems and equipment controlled by DDC system:

a. Operation of HVAC equipment in normal-off, normal-on, and failed conditions while observing individual equipment, dampers, and valves for correct position under each condition.
b. For HVAC equipment with factory-installed software, show that integration into DDC system is able to communicate with DDC controllers or gateways, as applicable.
c. Using graphed trends, show that sequence of operation is executed in correct manner, and HVAC systems operate properly through complete sequence of operation including seasonal change, occupied and unoccupied modes, warm-up and cool-down cycles, and other modes of operation indicated.
d. Hardware interlocks and safeties function properly and DDC system performs correct sequence of operation after electrical power interruption and resumption after power is restored.
e. Reporting of alarm conditions for each alarm, and confirm that alarms are received at assigned locations, including operator workstations.
f. Each control loop responds to set-point adjustment and stabilizes within time period indicated.
g. Sharing of previously graphed trends of all control loops to demonstrate that each control loop is stable and set points are being maintained.

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

K. Training Content for System Managers and Administrators:
1. DDC system software maintenance and backups.
2. Uploading, downloading, and offline archiving of all DDC system software and databases.
3. Interface with Project-specific, third-party operator software.
4. Understanding password and security procedures.
5. Adding new operators and making modifications to existing operators.
6. Operator password assignments and modification.

7. Operator authority assignment and modification.
8. Workstation data segregation and modification.

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

END OF SECTION

SECTION 237323 - CUSTOM OUTDOOR CENTRAL-STATION AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section Includes:
   1. Variable-air-volume, single-zone air-handling units.

1.3 ACTION SUBMITTALS

A. Product Data: For each air-handling unit indicated.
   1. Unit dimensions and weight.
   2. Cabinet material, metal thickness, finishes, insulation, and accessories.
   3. Fans:
      a. Certified fan-performance curves with system operating conditions indicated.
      b. Certified fan-sound power ratings in all eight octave bands. Include inlet or outlet sound power levels to coincide with sound requirements indicated on Drawings.
      c. Fan construction and accessories.
      d. Motor ratings, electrical characteristics, and motor accessories.
   4. Certified coil-performance ratings with system operating conditions indicated.
   5. Dampers, including housings, linkages, and operators.
   6. Filters with performance characteristics.

B. Sustainable Design Submittals:
   1. Product data showing compliance with ASHRAE 62.1.
   2. Product data showing compliance with ASHRAE 90.1.
   3. Product Data: For air filtration performance.

C. Delegated Design Submittals: For vibration isolation and seismic restraints indicated to comply with performance requirements and design criteria, including analysis data.
   1. For seismic restraints indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
      a. Include design calculations for selecting seismic restraints

1.4 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.

C. ARI Certification: Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.

D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

E. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

F. Comply with NFPA 70.

G. UVC Emitters: Each component and product is to be inbound and outbound tested before shipment under Mil Standard 105E and ANSI/ASQCZ 1.4. Output Verification: When tested in accordance with the general provisions of IES Lighting Handbook, 1981.

1.5 COORDINATION

A. Coordinate sizes and locations of structural steel bases with actual equipment provided.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Air Enterprises, Inc.
2. Air Flow Equipment.
3. Governair
4. Haakon.
5. Ingenia Technologies
6. Temtrol
7. Vertiv - Energy Labs
8. **<u>Johnson Controls Inc/York - York Custom</u> (Add. B)**
9. **<u>TMI Climate Solutions</u> (Add. B)**
10. **<u>XeteX</u> (Add. B)**

2.2 GENERAL

A. Provide the outdoor central station air handling unit(s) as shown and scheduled on the plans. Install the unit(s) in strict accordance with the specifications. Provide all units complete with fan section, coil section(s), filter section(s), and other accessories specified.

B. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design air-handling units, vibration isolation, and seismic restraints including comprehensive engineering analysis, using performance requirements and design criteria indicated.

C. Seismic Performance: Air-handling units shall withstand the effects of earthquake motions determined in accordance with ASCE/SEI 7.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2. Component Importance Factor: 1.5.

2.3 UNIT CASINGS

A. Design and build the unit specifically for outdoor installation. Design unit casing to be leakproof up to three-inch negative static pressure. Construct the unit so that the casing will be able to withstand up to twelve inches positive or negative static pressure. Construct all exterior wall panels of no less than 16-gauge galvanized steel welded to a 10-gauge welded galvanized steel base channel. Design unit to be double wall construction with a minimum of 22-gauge solid galvanized steel. Insulate with 100 mm (4-inch) thick insulation. Weld or bolt all seams, seal with a rubber-based mastic. Cover external vertical seams with a "U" clip, welded in place for additional weather protection. Insulate entire floor of unit in a manner so that interior floor of unit is all galvanized, thus preventing insulation erosion into the airstream.

B. Pitch galvanized roof for drainage and have it overlap the side panel on all four sides. Gasket and secure the roof to the wall panels with zinc coated steel screws. Gasket and bolt roof panel section joints together, with a "C" clip over panel joints for additional weather protection. Insulate roof panels in a manner so that ceiling of unit is all galvanized thus preventing insulation erosion into the airstream.

C. Finish all exterior surfaces of unit with vinyl chlorinated lacquer over phosphatized galvanized steel for corrosion protection. Provide custom paint color to match the screen wall color code / paint chip provided during the submittal review process.

D. Leakage: Casing leakage rate shall not exceed 1% of supply air volume at design static pressure up to positive or negative 12 inches.

E. Provide units with an insulated, double-wall, double-sloped stainless-steel drain pan under air intake, cooling coil and humidifier section(s) for positive drainage of condensate.

F. Extend all piping through the exterior casing and provide an air-tight seal around all penetrations.

G. Provide access compartments, a minimum of 610 mm (two feet) long.

H. Provide full size access doors in each access compartment and on both sides of the fan compartment. Provide access doors that are hinged, removable, double wall, with two-step safety handles operable from the interior and exterior of the unit, for quick access through the casing. Provide a 200 by 250 mm (8 by 10 inch) double glazed view window in each door. Provide a test port on each access door.

I. Provide in each module with an access door, a box mounted marine light fixture consisting of a cast aluminum housing with a corrosion resistant factory finish, thermal shock and impact resistant, clear glass lens fully gasketed and secured with a minimum of four fasteners and glass-filled, reinforced thermoplastic polyester lamp guard.

J. Provide a box mounted light switch with pilot light at the fan section of each unit. Provide a junction box and a duplex receptacle adjacent to the switch for site power connection by Division 26. Provide conduit and wiring from the switch to each light in the unit. At each shipping break point, provide a pair of junction boxes with a length of seal-tite conduit extending from one box for field connection to the adjacent box, making up the wire connections with wire nuts in the box.

K. Provide door switches wired to interrupt the power to the ultra violet microbial control system at any door whose compartment has line of sight to the UV protected area from any location in the compartment.

L. Provide all electrical components in accordance with the requirement of NFPA 70 and Division 26.

M. Construct units of solid double-wall construction to prevent insulation erosion into the airstream and to allow cleaning of the unit interior. Construct interior wall of 16 gage solid plate galvanized steel, insulated with 101-mm- (four-inch-) thick, closed cell polyurethane foam insulation. Insulate connecting channels to prevent sweating.

2.4 CLOSING-OFF SHEETS

A. Provide closing-off sheets to close spaces around coils, filters, blenders, dampers and other equipment to prevent by-pass of air around these units.

B. Construct closing-off sheets of 18 gage galvanized metal connected to the equipment casing and the plenum chamber or ducts using approved methods of fastening to obtain an air-tight joint.

2.5 MIXED AIR BLENDER SECTION

A. Provide the units with a blender section consisting of air blenders and mixing box sections fitted together in one rigid unit, as shown on the Drawings.

B. Provide sections with the same double-wall insulated casing as specified for the air handling units. Size units to match the air handling unit dimensions without transitions or field modifications.

C. Fabricate the blenders up through 2250-mm (90-inch) size of 2-mm (0.080-inch)-thick aluminum and blenders 2400-mm (96-inche) size and larger of 3-mm (0.125-inch) thick aluminum, all welded multiple static mixing devices.

D. Design the blenders to impart a counter rotational mixing in the air streams relative to each other.

E. Install the blender sections with proper distances such that the blender will provide a minimum mixing effectiveness of 75 percent and +/- -3.3 deg C (-6 deg F) standard deviation when mixing 50 percent outside air with 50 percent return air at 10 deg C (50 deg F) inlet temperature differential, and minimum mixing effectiveness of 80 percent and +/- -29.5 deg C (- 5 deg F) standard deviation when mixing 30 percent outside air with 70 percent return air at 10 deg C (50 deg F) inlet temperature differential.

F. Design the blenders to perform at face velocities of from 150 to 760 m/m (500 to 2500 fpm) with no loss in mixing performance. Pressure drop at blender velocity of 150 m/m (500 fpm): 3.5 Pa (0.14-inch w.g.).

G. Blenders fabricated with turning vane type devices are not acceptable.

H. Manufacturer: Blender Products, Inc. of Denver, Colorado, ÓSeries IV Blender Sectio n .

2.6 COIL SECTION

A. Provide coils as scheduled on the Drawings and specified in Section 238216.

2.7 AIR FILTRATION SECTION

A. Provide filter frames, racks, and filters as scheduled on the Drawings and specified in Section 234100.

2.8 ENERGY RECOVERY WHEELS

A. Provide energy recovery wheels as scheduled on the Drawings and specified in Section 237200.

B. Provide variable-frequency controller and disconnect switch. Refer to Section 262923 for Variable Frequency Motor Controllers.

2.9 HUMIDIFIERS

A. Provide humidifiers as scheduled on the drawings and specified in Section 238413.

2.10 FANS

A. Provide fans as scheduled on the drawings and specified in Section 233416.

B. Isolate fan and motor assembly from unit casing with spring isolators, minimum 1" deflection. Refer to Section 230548.

C. Attach fan inlet to unit casing by means of a flexible connection. Refer to Section 233300.

D. Backdraft Damper: Provide a backdraft damper at the inlet of each fan in the array to prevent air circulation through any fan that is not operating. Design backdraft damper ww assembly to operate with little to no static pressure loss with fan operating throughout the entire operating range from design to minimum airflow.

2.11 Each fan array shall consist of multiple fans and motors, spaced in the air way tunnel cross section. Provide a dedicated variable-frequency controller for each fan/motor assembly in the fan array. Wire individual VFD's to an exterior unit mounted NEMA 1 power distribution panel (PDP) with disconnect switch for each array. Refer to Section 262923 for Variable Frequency Motor Controllers. ULTRAVIOLET MICROBIAL CONTROL SYSTEM

A. General
   1. Provide in the air-handling unit air tunnel downstream of the cooling coil at right angles to the coil fins such that Ultraviolet-C (UVC) light energy bathes all surfaces of the coil and drain pans, an ultraviolet microbial control system for HVAC mold, bacteria and odor control.

B. Emitters
   1. Provide UL compliant UVC emitters: Comply with UL Standard 1995 as applicable to usage of UVC emitters in HVAC Equipment.

2. Provide the assembly consisting of a housing, power source, reflector, emitter sockets and emitter all constructed to withstand the environment inside and air handling unit housing of from 1.7 to 76.7 deg C (35 to 170 deg F) at 100 percent relative humidity and at any velocity.
3. Intensity-Shall be measured by a Solid-State Photodiode UV Sensor at the coil. Calibration wavelength is 254 nm. Testing shall be done during cooling coil operation in ambient air temperatures of 55 F. Accuracy is to be _+ 10% and be NIST traceable. Operating range shall be 320 F- 1580 F. Read by a Display module with a 3.5-digit LCD screen/panel. Irradiance range shall be 0-1999 (x10) µW/cm2 with a resolution of 10 µW/cm at 50 degrees F.
4. Emitter tube shall be of the high output, hot cathode, T5 diameter, and medium bi-pin type. They shall produce 95% of their energy at 254 nm and be capable of producing the specified output at airflow velocities to 1000 fpm at temperatures of 35 - 170° F. UVC Emitters shall produce no ozone or other secondary contamination.

C. Housings
1. Fabricate the housings of hospital grade stainless steel equipped with NPS ½ DN 15 conduit openings on each end.

D. Power Sources
1. Provide the units with a Class P2, rapid start type power source with a power factor of 0.99 and an efficiency of not less than 86 percent. Provide the units rated at 115 Vac, 60 Hz and 70 to 85 watts. Provide the units with RF and EMI suppression, smart “End of Lamp Life” protection and an integral circuit breaker.
2. Provide units with a contact for door switch interruption of power.

E. System Design Performance
1. Each UVC system shall be designed to deliver minimum and average intensities (µW/cm2) on irradiated surfaces. The minimum intensity, however, shall never be less than 1225 µW/cm2 at the four corners (extreme position is defined as one square centimeter of irradiated surface at one corner of the area covered by the lamp) of the irradiated surface. The supplier of the UVC system shall provide documentation demonstrating the calculations for the specified minimum and average intensities for each UVC system during the submittal process.

F. Reflectors
1. Provide the unit reflectors fabricated of heavy gauge, specular finished aluminum alloy, with a minimum 86 percent reflectance at 254 nm.

G. Sockets
1. Provide the units with medium bi-pin, double click safety, twist lock type sockets, fabricated of a UVC resistant polycarbonate.

H. Manufacturers
1. Sterile-Aire USA, Inc, UltraViolet Devices, Inc., or as approved.

2.12 UNIT HEATER

A. Provide a UL approved electric unit heater as scheduled, with a properly sized, weatherproof enclosed, circuit breaker. Ship unit heater and circuit breaker separate for field installation. Provide wiring from the installation location for the unit heater through electrical conduit, to a weatherproof junction box, located near the motor and light junction box. Design unit heater to maintain a preset temperature in the service corridor.

2.13 AIR INTAKE LOUVER

A. Provide air intake louver as shown on the Drawings and specified in Section 089119.

2.14 WALKWAY GRATING

A. Provide removable welded steel walkway grating over the supply and return air inlet in the unit as well as at the piping floor opening in the service corridor suitable for application of a concentrated load of not less than 225 kg (500 pounds) at the midpoint of the short-way span, with an associated deflection of not more than 6 mm (1/4 inch).

B. Fabricate bearing bars of not less than 25 mm (1 inch) by 4.8 mm (3/16 inch), spaced 30 mm (1-3/16 inches) on center with individual grating sections having no dimension greater than 1 meter (3 feet) and equipped with safety chains. Provide safety chains and attachments capable of supporting not less than twice the weight of the associated grating sections.

2.15 SOURCE QUALITY CONTROL

A. Fan Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.

B. Fan Performance Rating: Factory test fan performance for airflow, pressure, power, air density, rotation speed, and efficiency. Rate performance according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating."

C. Water Coils: Factory tested to 300 psig according to ARI 410 and ASHRAE 33.

2.16 FACTORY-MANUFACTURED ROOF CURBS

A. General:
1. Air-handling unit manufacturer shall furnish a continuous perimeter curb for each roof-mounted air-handling unit.
2. Design curb to support operating air-handling unit from its base with attachments to withstand environmental forces. Curbs with intermediate reinforcing as required.
3. Frame curb for ductwork, piping, and conduit located within curb.
4. Fabricate curb to maintain top of curb level even where installed on sloping substrate.
5. Furnish top of curb to provide for field attachment of unit base to curb.
6. Furnish curb with a fully mitered and raised can’t where required by adjacent insulation and roofing.
7. Include bottom of curb with attachment flange that extends beyond base of curb and is suitable for attachment to substrate.

8. Furnish curb with integral crickets if required by roof installation.

B. Size:
1. Size curb to provide continuous support of unit base and to fit within footprint of unit perimeter base.
2. Height:

a. See Drawings.

C. Materials:

1. Galvanized-Steel Solid Sheet: ASTM A653/A653M; G90 coating. Treat welded areas to protect against corrosion with a zinc-rich coating.

D. Insulation:
1. Insulate curb to provide thermal performance equal to unit casing.
2. Completely encapsulated insulation within metal curb.

E. Gaskets:
1. Include a continuous gasket between air-handling unit base and top of curb for an air and watertight seal.
2. Select gasket materials suitable for installation while complying with requirements indicated.
3. Furnish gasket materials with air-handling units and curbs for field installation.
4. Air-handling unit manufacturer to provide instruction to installer on proper installation techniques.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine casing insulation materials and filter media before air-handling unit installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.

C. Examine roughing-in for steam, hydronic, and condensate drainage piping systems and electrical services to verify actual locations of connections before installation.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install separately shipped filters in the factory-installed frames and racks.

B. Equipment Mounting: Install air-handling units at locations indicated on Drawings.
1. Install air-handling units on curbs following air-handling unit manufacturer's written procedures.
a. Install gaskets before setting air-handling units on curbs.
b. Secure air-handling units to curbs using stainless steel fasteners.
c. Install curb and fasten to structure.
d. Coordinate curb requirements, attachment, and location before installation.

C. Roof Openings:

1. Provide exact size and location of roof openings to trade installing structural framing and roof structure.
2. Supervise framing of openings to ensure coordinated installation with air-handling units.

D. Vibration and Seismic Control: Comply with requirements for vibration and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC." and as noted on the drawings.

E. Equipment Clearances and Access:
1. Arrange installation of air-handling units to provide access space around air-handling units for service and maintenance and for removal and replacement of internal components.
2. Provide clearance and access required by governing codes and NFPA 70.
3. At a minimum, comply with requirements indicated on Drawings and air-handling unit manufacturer's written instructions.

F. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.

3.3 CONNECTIONS

A. Comply with requirements for piping specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to air-handling unit to allow service and maintenance.

C. Connect condensate drain pans using NPS 1-1/4, ASTM B 88, Type M copper tubing. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.

D. Hot- and Chilled-Water Piping: Comply with applicable requirements in Section 232113 "Hydronic Piping." Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.

E. Connect duct to air-handling units with flexible connections. Comply with requirements in Section 233300 "Air Duct Accessories."

3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

B. Perform tests and inspections.
1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

C. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.

D. UVC System Commissioning: UVC system shall be commissioned by manufacturer field representative. Commissioning shall verify system intensity level for each UVC system demonstrating they have met or exceeded the minimum and average UVC intensities as specified above in the system performance. The commissioning shall be performed upon installation of UVC system for each AHU during operating conditions. Points of measurements for UVC system minimum intensity shall be demonstrated by measuring at the four extreme corners (extreme position is defined as one square centimeter of coil at one corner of the area covered by the lamp) of the coil surface in the same plane as the irradiated surface. Each corner shall meet or exceed specified minimum intensity as defined in the system performance. Additionally points of measurements shall be taken every four (4) square feet across the face of the coil. The average intensities shall be calculated by averaging the four (4) corner measurements with those measurements taken every four (4) square feet. Points of measurement shall be made using an International Light or similar calibrated radiometer/photometer accurate to + 3% radiometric and photometric for NIST transfer standards in the monochromatic irradiance at 254nm or similar. This shall be used to verify compliance. Upon completion of the commissioning report demonstrating and verifying design intensity level and actual recorded level as well as all measurement locations shall be presented upon submission of Operation and Maintenance manuals.

3.5 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.
   1. Complete installation and startup checks according to manufacturer's written instructions.
   2. Verify that shipping, blocking, and bracing are removed.
   3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
   4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
   5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
   6. Verify that zone dampers fully open and close for each zone.
   7. Verify that face-and-bypass dampers provide full face flow.
   8. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
   9. Comb coil fins for parallel orientation.

B. Starting procedures for air-handling units include the following:
   1. Measure and record motor electrical values for voltage and amperage.
   2. Manually operate dampers from fully closed to fully open position and record fan performance.

3.6 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for air-handling system testing, adjusting, and balancing.

3.7 CLEANING

A. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

3.8 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

END OF SECTION

SECTION 238214 - CHILLED BEAMS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Active chilled beams.

B. Related Requirements:

   1. Section 013573 "Delegated Design Requirements and Procedures" for definitions, submittal procedures, responsibilities, and scheduling requirements associated with delegated design assignment indicated in this Section.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.
   1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for chilled beams.
   2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories for chilled beams.
   3. Submit sufficient information needed for direct comparison to each entry scheduled on Drawings.
   4. Submit manufacturer's velocity and temperature profiles beneath passive chilled beams under conditions obtained in accordance with BS EN 14518 test procedures to show compliance.

B. Shop Drawings: For chilled beams.
   1. Include plans, elevations, sections, and attachment details.
   2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   3. Include diagrams for power, signal, and control wiring.

C. Delegated Design Submittal: Refer to Section 013573 "Delegated Design Requirements and Procedures" for delegated design submittal procedures and requirements.
   1. Provide delegated-design submittal for chilled beams.
      a. Include design calculations for selecting mounting and seismic restraints.

1.3 INFORMATIONAL SUBMITTALS

A. Seismic Qualification Data: Certificates for chilled beams, accessories, and components, from manufacturer.
   1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

B. Field quality-control reports.

C. Sample Warranty: For manufacturer's warranty.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a registered design professional, as defined in Section 013573 "Delegated Design Requirements and Procedures" to design chilled beams.
   1. Material properties indicated in this Section shall be considered as minimum properties.

B. Seismic Performance: Chilled beams shall withstand the effects of earthquake motions determined in accordance with ASCE/SEI 7. See Section 230548 "Vibration and Seismic Controls for HVAC."

   1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

   2. Component Importance Factor: 1.5.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.

D. Capacities and Characteristics:
   1. See Drawings.

2.2 ACTIVE CHILLED BEAMS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Dadanco USA.
   2. Halton Company.
   3. Price Industries.
   4. SEMCO, LLC; part of FlaktGroup.
   5. Swegon Inc.
   6. Titus.
   7. **<u>Carson Solutions</u>** **(Add. B)**

B. Source Limitation: Obtain chilled beams from single manufacturer.

C. Description: Sheet metal casing with primary-air, secondary-air, and mixed-air plenums; air nozzles; air inlet grille; supply-air discharge slot(s); cooling and heating hydronic coil assembly; mounting brackets; and accessories suitable for location and mounting arrangement indicated on Drawings.

D. Components:
   1. Casing:

a. Materials, Exposed Units: Minimum 0.0375-inch- thick, galvanized-steel sheet.
b. Materials, Recessed Units: Minimum 0.0375-inch- thick, galvanized-steel sheet.
c. Mounting Brackets: Factory installed along long side of units, with not less than four supports located near corners of units; field adjustable.
d. Commissioning Ports: Equip chilled beams with commissioning ports for field measurement of static pressure differential between primary-air plenum and room. Include an airflow calibration chart attached to each chilled beam.
e. Casing Leakage: Factory seal casing joints, seams, and penetrations of casing positive-pressure plenums to be airtight. Leakage in primary-air plenum shall not exceed 5 percent of airflow rate indicated on Drawings.
f. Primary-Air Plenum Duct Connections: Round or oval collar of sufficient length to accommodate a slip-on field-installed duct. Size as indicated on Drawings

g. Insulation: Exterior or interior portions of casing capable of forming surface condensation shall be insulated with fiber-free insulation to prevent condensation.

h. Blank (Filler) Sections: Where indicated on Drawings, chilled-beam manufacturer shall furnish blank (filler) sections to match external appearance of adjoining active portions.

i. Multiple Section Mating and Alignment: Where multiple sections are required to join end to end to make a longer contiguous unit, manufacturer to provide means to join multiple sections, so they appear as a single unit with no obvious obstructions or visual cues of multiple sections.

2. Air Nozzles: Quantity, size, and arrangement selected by chilled-beam manufacturer for performance indicated on Drawings. Primary air supplied through nozzles shall induce room (secondary) air across hydronic coil, and two air steams shall mix to supply conditioned air to room.

   a. Material: Metal or plastic, complying with NFPA 90A and UL 94 V-0.

3. Inlet Air Grille: Mounted on face of chilled beam and arranged for room (secondary) air to enter grille and hydronic coil before mixing with primary air.
   a. Perforated face with 50 percent free area.
   b. Hinged on one or two sides to open from room side.
   c. Removable from room side without use of tools.
4. Supply-Air Discharge Slot(s): Size and arrangement selected by chilled-beam manufacturer for performance indicated on Drawings.
   a. Material: Extruded aluminum or formed steel.

   b. Field-Adjustable Discharge-Air Pattern: Include field-adjustable air pattern control to adjust the direction of the discharge air.

5. Hydronic Coil: Copper tube mechanically bonded to aluminum fins and mounted in a galvanized-steel coil casing; rated for minimum working pressure of 300 psig.
   a. Tube Thickness: Minimum 0.016-inch thick.
   b. Fluid Tube Velocity (at Chilled-Water Design Flow Rate):
      1) Maximum: 4 fps.
      2) Minimum: 1 fps.
   c. Fin Thickness: Minimum 0.006-inch thick.
   d. Fin Spacing: No closer than 12 fins per inch.
   e. Field Piping Connections: Press, Push-on, Solder, or Threaded ends with terminations oriented for field connection, as indicated on Drawings.
   f. Piping Arrangement: Four pipe, as indicated on Drawings.

   g. Include coil with manual air vent and drain fitting.
   h. Include vertical-oriented coil(s) with drain pan constructed of galvanized steel and sloped at least 1 percent toward a NPS 1/2 capped drain connection.

E. Finish: Powder coat.
   1. Color: Manufacturer's standard paint color, as selected by Architect. Custom color where noted on the drawings.
   2. Appearance of Finished Work: Variations in same piece are unacceptable. Variations in appearance of adjoining components are acceptable if they are within the range of approved Samples and are assembled or installed to minimize contrast.

F. Accessories:

   1. Hoses: NPS 1/2; 24 inches long; PTFE-lined flexible hose wrapped in a stainless-steel braided jacket and fitted with NPT threaded swivel ends; rated for 300 psig.
   2. Primary Airflow Manual Dampers: Integral damper assembly with locking handle for field adjustment.
   3. Coanda Wings (where noted on drawings).
      a. Manufacturer shall supply six-inch wide coanda wings or exposed casing for open ceiling installations. Wings and exposed casings shall be constructed of 20 gauge painted steel or 0.060-inch-thick aluminum extrusion and installed with no fasteners or hardware visible from the room side.
   4. Access panel (where noted on drawings).
      a. A blank section shall be provided at the end of the beam to allow easy access to piping connections, and shall be seamless with a blank-off plate blocking the enclosure section.

G. Source Quality Control: Comply with ASHRAE 200, AHRI 1240, and AHRI 1241.
   1. Rate capacity of coils in accordance with AHRI 410, with capacities established in accordance with ASHRAE 200.

2.3 GENERAL PROTECTION REQUIREMENTS

A. Protect finishes on exposed surfaces from damage by applying a removable, temporary protective covering at the factory before shipping.

B. Protect coil and piping openings with removable end caps before shipping.

C. Protect duct connection openings with removable end caps before shipping.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas to receive chilled beams for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for duct, piping and wiring to verify actual locations of connections before installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install chilled beams level and plumb.

B. Coordinate layout and installation of chilled beams and suspension-system components with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, communications system, security system, and partition assemblies.

C. Seismic Restraints: Comply with requirements for seismic-restraint devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

D. Comply with requirements for pipe hangers and supports specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

E. Install continuous-thread hanger rods of size required to support chilled-beam weight. Laterally brace chilled beams to prevent movement.

3.3 PIPING CONNECTIONS

A. Comply with requirements for piping specified in Section 232113 "Hydronic Piping" and Section 232116 "Hydronic Piping Specialties." Drawings indicate general arrangement of piping, fittings, and specialties.

B. Comply with requirements for general-duty valves specified in Section 230523 "General-Duty Valves for HVAC Piping,"

C. Make piping connections to chilled-beam units at locations indicated on Drawings.

D. Where installing piping adjacent to chilled beams, allow space for service and maintenance.

3.4 DUCT CONNECTIONS

A. Comply with requirements for ductwork specified in Section 233113 "Metal Ducts." and Section 233300 "Air Duct Accessories." Drawings indicate general arrangement of ductwork.

B. Make ductwork connections to chilled-beam units at locations indicated on Drawings.

C. Where installing ductwork adjacent to chilled beams, allow space for service and maintenance.

3.5 CONTROLS

A. Comply with requirements for controls specified in Section 230923 "Direct Digital Control (DDC) System for HVAC."

3.6 IDENTIFICATION

A. Identify hydronic piping and valves. Comply with requirements specified in Section 230553 "Identification for HVAC Piping and Equipment."

3.7 CLEANING AND PROTECTION

A. Protect exposed surfaces of chilled beams from damage with factory-installed protective covering. Maintain covering in place until start of unit testing and balancing.

B. Protect chilled beam water connections with factory-installed protective covers, and keep them covered until making final field piping connections.

C. Protect chilled-beam air connections with factory-installed protective covers and keep them covered until making final field duct connections.

D. Clean chilled beams inside and out to a factory-new condition.

E. Reject damaged chilled beams and replace with new units.

F. Only if acceptable to the Owner, minor damage to finishes may be repaired as required to restore beams to factory-new appearance. Any variation in visual appearance between factory and repaired finish shall be rejected.

3.8 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

B. Tests and Inspections:
   1. Leak Test: After installation, fill system with water under design pressure and test for leaks. Repair leaks and retest until no leaks exist.

C. Chilled beam will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

3.9 ADJUSTING

A. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

3.10 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain chilled beams.

END OF SECTION