ASHRAE GUIDELINE 13-2024

SPECIFYING BUILDING AUTOMATION SYSTEMS

EXAMPLE SPECIFICATION

The following sample specification is aligned with the guidance provided in Sections 12 to 14 of ASHRAE Guideline 13-2024. This document may be copied and edited by the user to prepare a project specific specification. The document follows the CSI Master Format Numbering and aligns with elements of both Divisions 23 09 and 25 00. Users may need to edit the specific scope of the document to meet project requirements.

# GENERAL

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## PROJECT SUMMARY

* + 1. [Provide an overall description of the project that this specification is part of. Include project goals, objectives, and discipline scope that is relevant to this specification. Refer to description of work and other trades, especially with regards to any normative requirements. Refer to ASHRAE Guideline 13 for additional information that may be included in the project summary such as the project specific version of the four-tier physical system architecture and the BAS Infrastructure and cybersecurity plan.]

## DEFINITIONS AND ABBREVIATIONS

* + 1. BACnet Specific Definitions
       1. BACnet: Building Automation Control Network Protocol (ANSI/ASHRAE Standard 135). A communications protocol allowing devices to communicate data and services over a network.
       2. BACnet Interoperability Building Blocks (BIBB): BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBs are combined to build the BACnet functional requirements for a device.
       3. BACnet/IP: Defines and allows using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP subnetworks that share the same BACnet network number.
       4. BACnet Testing Laboratories (BTL): Organization responsible for testing products for compliance with ASHRAE Standard 135, operated under direction of BACnet International.
       5. Protocol Implementation Conformance Statement (PICS): Written document that identifies the particular options specified by BACnet that are implemented in a device.
    2. General Terminology
       1. Authentication: The act of verifying identity (see BACnet 135)
       2. Backbone: communication system that transfers data between components
       3. BAS Server: A computer server that maintains the BAS systems configuration and programming database. BAS servers may be dedicated physical servers or virtual servers operating as part of a virtual machine (see *Server* and *Virtual Machine*).
       4. Bidirectional: Often ascribed to hydronic flowmeters that may measure flow in either direction within a pipe.
       5. Bridge: A device that routes messages or isolates message traffic to a particular segment subnet or domain of the same physical communication media.
       6. Change of State: An event that occurs when a measured or calculated Boolean or discrete enumerated value changes.
       7. Controller: Intelligent stand-alone control device. *Controller* is a generic reference to building controllers, custom application controllers, and application-specific controllers.
       8. Direct Digital Control (DCDC): A type of control where controlled and monitored analog or binary data (e.g., temperature, contact closures) are converted to digital format for manipulation and calculations by a digital computer or microprocessor, then converted back to analog or binary form to control physical devices.
       9. Fault Detection and Diagnostics (FDD): An analytic tool that identifies faults in HVAC systems and provides advice based on predefined rules for how to address those problems.
       10. Feedback Control: A control system in which the effect of the control action on the controlled variable is sensed and used by the controller to provide a new output (feedback control).
       11. Firmware: Software (programs or data) that has been written to read-only memory (ROM). Firmware is a combination of software and hardware.
       12. Gateway: Bidirectional protocol translator connecting control systems that use different communication protocols.
       13. Graphical User Interface (GUI): A form of user interface that allows users to interact with electronic devices through graphical icons and visual indicators, such as secondary notation, rather than through typed commands or via text navigation.
       14. Hub: An IT hardware device that allows for multiple IP devices to connect to a single uplink channel. Hubs pass all information from the uplink to all downlink ports and therefore do not isolate network traffic.
       15. Internet Protocol (IP): An IP addresses is an identifier for a computer or device on a TCP/IP network. Most networks combine IP with a higher-level protocol called Transmission Control Protocol (TCP), which establishes a virtual connection between a destination and a source. Networks using the TCP/IP protocol route messages based on the IP address of the destination.
       16. Interoperability: Interoperability is a characteristic of a product or system, whose interfaces are completely understood to work with other products or systems, at present or in the future, in either implementation or access and without restrictions. It enables the exchange of data between multivendor devices and control applications without proprietary restrictions. Interoperability does not imply interchangeability. To help BAS Designers, contractors, and owners, several certification programs have been established that offer testing methods to certify conformance with a given interoperable protocol. Examples of protocols with certified interoperability include BTL, LON, and OPC.
       17. Local Area Network (LAN): Computer or control system communications network limited to a local building or campus.
       18. Manager-Subordinate/Token Passing: Data link protocol as defined by the open-protocol standard. See Informative Appendix F for a reference to open-protocol guideline specification language.
       19. Modbus RTU: Modbus RTU is an open, serial (RS-232 or RS-485) protocol derived from the manager-subordinate architecture. It is a widely accepted protocol due to its ease of use and reliability. Modbus RTU is widely used within building automation systems.
       20. Network Topology: Network topology is the arrangement of the elements (links, nodes, etc.) of a communication network. A wide variety of physical topologies have been used in LANs, including ring, bus, mesh and star. Some protocols allow for free topology where star, loop, bus or mixed topology may be used within an overall LAN but a given subnetwork normally follows the same topology. Topologies are either physical or logical.
       21. Owner: Term used in ASHRAE Guideline 13 to refer to the owner or facility manager of a particular building or facility in which the BAS is installed. The term “client” is reserved for a computer or other device that interrogates the BAS equipment, as in client/server model.
       22. Proportional–Integral–Derivative (PID) Control: A control-loop feedback mechanism widely used in control systems and a variety of other applications requiring continuously modulated control.
       23. Point-to-Point: Serial communication as defined in the open-protocol standard. See Informative Appendix F for a reference to open-protocol guideline specification language.
       24. Positive Positioner: A pneumatic relay used to accurately position an actuator with respect to signal pressure from a controller. It can also be used to change the effective spring range of an actuator and increase the capacity of a controller.
       25. Protocol: A (communication) protocol is a system of rules that allows two or more entities of a communications system to transmit information via any kind of variation of a physical quantity. The protocol defines the rules, syntax, semantics, and synchronization of communication and possible error recovery methods. Protocols may be implemented by hardware, software, or a combination of the two.
       26. Router: A device that routes or forwards messages destined for a node on another subnet or domain of the control network. The device controls message traffic based on node address and priority. Routers may also serve as communication bridges between different channel media (i.e., power line, twisted pair, radio frequency, and Ethernet).
       27. Server: Servers may be dedicated or virtual. Servers are often dedicated, meaning that they perform no other tasks besides their server tasks. Dedicated servers typically refer to a dedicated computer with a single operating system connected to a network providing dedicated server tasks. Examples include proxy servers, mail servers, application servers, web servers, FTP servers, etc. A virtual server mimics dedicated server features. A virtual server is designated with a separate operating system (OS), e.g., Windows Server, with independent reboot provisions. Multiple virtual servers may be hosted on one dedicated server. Virtual servers may also be referred to as virtual machines (VM) though not all VMs are virtual servers.
       28. Switch: An IT hardware device that allows multiple IP devices to connect to and transfer information on an IP network and that is used to extend the number of IP devices on a network.
       29. Terminator: A device comprising a capacitor and a resistive element that provides electrical termination for signals on a given channel type.
       30. Virtual Machine (VM): A VM is a software program or operating system that emulates the behavior of a separate, dedicated physical computer capable of performing tasks such as running applications and programs like a separate computer. One or more VMs may be hosted by a singled dedicated host computer.
       31. Virtual Points: A virtual point is an I/O object that may not be associated with any physical hardware, as it has been extracted, derived, or calculated form other than a physical connection to a control device.
       32. Virtual Private Network (VPN): A VPN is an encrypted connection over the Internet from a device to a network.
       33. Windup: “Integral windup,” also known as “integrator windup” or “reset windup,” refers to the situation in a PID feedback controller where a large change in set point occurs (say a positive change) and the integral terms accumulate a significant error during the rise (windup), thus overshooting and continuing to increase as this accumulated error is unwound (offset by errors in the other direction). The specific problem is the excess overshooting.
       34. Wiring: Raceway, fittings, wire, boxes, and related items.
    3. Abbreviations
       1. A/D analog-to-digital
       2. AHJ authority having jurisdiction
       3. ASCapplication-specific controllers
       4. BASbuilding automation system
       5. CACcustom application controllers
       6. CCTVclosed-circuit television
       7. CSACanadian Standards Association
       8. CSI Construction Specifications Institute
       9. CxA commissioning authority/agent
       10. DDCdirect digital control
       11. DPDTdouble-pole, double-throw
       12. DPSTdouble-pole, single throw
       13. FSCSfirefighter’s smoke control station
       14. FMSIFacility Master System Integrator
       15. GUI graphical user interface
       16. HMI human machine interface
       17. IoT Internet of Things
       18. NECNational Electric Code (NFPA 70)
       19. NEMANational Electrical Manufacturers Association
       20. NISTNational Institute of Standards and Technology
       21. NRTLnationally recognized testing laboratory
       22. PICVpressure-independent control valve
       23. PID proportional-integral-derivative (PID)
       24. RTDresistance temperature detectors
       25. RTUroof-top unit
       26. SPDTsingle-pole, double-throw
       27. SSL secure socket layer
       28. SOAPSimple Object Access Protocol
       29. SQLStructured Query Language
       30. TCP/IPTransmission Control Protocol/Internet Protocol
       31. UPSuninterruptable power supply
       32. VFDvariable-frequency drive
       33. VLANvirtual local-area network
       34. WANwide-area network

## REFERENCE STANDARDS

* + 1. Work under this section is subject to requirements of contract documents, including general conditions, supplementary conditions, and sections under Division 01, “General Requirements.”
    2. The latest edition of the following standards and codes, in effect and amended as of supplier’s proposal date, and any applicable subsections thereof shall govern design and selection of equipment and material supplied:
       1. ASHRAE
          1. ANSI/ASHRAE Standard 135, *BACnet*
          2. ASHRAE Guideline 36, *High-Performance Sequences of Operation for HVAC Systems*
       2. *International Building Code* (IBC), including local state and local amendments.
       3. *International Mechanical Code* (IMC)
       4. *International Energy Conservation Code* (IECC)
       5. *International Plumbing Code* (IPC)
       6. Underwriters Laboratory, LLC
          1. UL 508, *Industrial Control Equipment*, and UL 508a, *Training on Industrial Control Panels* (U.S. and Canada)
          2. UL 916, *UL Standard for Safety Energy Management Equipment* (U.S. and Canada)
       7. *National Electrical Code* (NEC)
       8. FCC Part 15, Subpart J, Class A
       9. EMC Directive 89/336/EEC (European CE Mark)
       10. State and federal regulations and codes in effect as of contract date
    3. Performance Standards. System shall conform to the following minimum standards over network connections:
       1. Graphic Display. A graphic with 20 dynamic points shall display with current data within ten seconds.
       2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within eight seconds.
       3. Object Command. Devices shall react to command of a binary object within two seconds. Devices shall begin reacting to command of an analog object within two seconds.
       4. Object Scan. Data used or displayed at a controller or workstation shall have been current within the previous six seconds.
       5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 45 seconds.
       6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every five seconds. Select execution times consistent with the mechanical process under control.

## PERMITS AND FEES

* + 1. In accordance with general conditions of contract.
    2. Except as otherwise indicated, the system supplier shall secure and pay for all permits, inspections, and certifications required for his work and arrange for necessary approvals by any outside governing authorities.
    3. Submit certificate of acceptance from authority having jurisdiction to owner.

## COORDINATION WITH OTHER TRADES

* + 1. The following table is intended to assist the contractors in coordinating the scope of work between Division 25, “Integrated Automation” (indicated as 25) and other divisions as indicated.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Trade Coordination and Responsibility Matrix | | | | | |
| System | Equipment | Installation | Power Wiring (Remark) | Control and Interlock Wiring (Remark) | See Note(s) |
| Fire and Life Safety Systems | | | | | |
| 1. Smoke dampers with electric actuators used also for HVAC control | 23 | 23 | 26 | 25/26 | 2 |
| Mechanical Equipment | | | | | |
| 2. Unitary mechanical equipment | 23 | 23 | 26 | 25/26 | 3, 8 |
| 3. Chillers | 23 | 23 | 26 | 25 | 3, 7 |
| 4. Variable-speed drives, field mounted | 23 | 26 | 26 | 25/26 | 4, 8 |
| 5. Motor starters, three-phase | 26 | 26 | 26 | 25/26 | 5, 8 |
| 6. Other powered equipment | 23 | 23 | 26 | 25 |  |
| 7. Refrigerant leak detector | 25 | 25 | 26 | 25 | 9 |
| 8. Unit and cabinet heaters | 23 | 23 | 26 | 23/25 | 10 |
| 9. Cooling tower vibration switch | 23 | 23 | — | 25 |  |
| 10.Cooling tower water treatment system | 23 | 23 | 26 | 25 | 11 |
| Building Automation System (BAS) | | | | | |
| 11.Central control workstations and servers | 25 | 25 | 26 | 25 |  |
| 12.Control system network backbone | 25 | 25 | 25 | 25 |  |
| 13.Line voltage control devices to 120V motors | 25 | 26 | 26 | 26 | 6 |
| 14.Window switches | 25 | 25 | — | 25 |  |
| 15.Control panels | 25 | 25 | 26/25 | 25 | 12 |
| 16.Control devices | 25 | 25 | 25 | 25 |  |
| Electrical Systems | | | | | |
| 17.Lighting control network gateway | 26 | 26 | 26 | 25 | 13 |
| 18.Power monitoring sensors and gateway | 26 | 26 | 26 | 26/25 | 14 |
| Emergency Power Support Systems | | | | | |
| 19.Generator monitoring and alarm points | 26 | 26 | — | 25 | 15 |
| 20.Generator fuel system | 22/26 | 22/26 | 26 | 25 | 16 |
| Irrigation System | | | | | |
| 21.Flowmeters | 25 | 32 | 25 | 25 |  |
| Plumbing Systems | | | | | |
| 22.Gas and water flowmeters | 25 | 22 | 25 | 25 |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 23.Recirculation pumps or heat tape | 22 | 22 | 26 | 25 |  |
| 24.HHW to DHW controls | 25 | 22/23 | 25 | 25 |  |
| 25.Sensor wells, meters and other pipe-mounted control devices | 25 | 22 | 25 | 25 |  |
| HVAC Hydronic Systems | | | | | |
| 26.Automatic isolation and control valves | 25 | 23 | 25 | 25 |  |
| 27.Sensor wells, meters and other pipe-mounted control devices | 25 | 23 | 25 | 25 |  |
| Kitchen Exhaust Systems | | | | | |
| 28.Grease hoods | 11 | 11 | — | 25 | 17 |
| 29.Grease hood pollution control unit (PCU) | 23 | 23 | 26 | 25 |  |
| 30.Grease hood demand control ventilation systems | 11 | 25 | 26 | 25 | 18 |
| HVAC Sheet Metal | | | | | |
| 31.Duct mounted sensors | 25 | 23 | 25 | 25 |  |
| 32.Filter gages | 25 | 25 | — | — |  |
| 33.Control damper actuators | 25 | 25 | 25 | 25 | 19, 20 |
| Computer Room Air-Conditioning Systems | | | | | |
| 34.AC unit including all controls | 23 | 23 | 23 | 25 |  |
| 35.Leak detectors | 23 | 23 | — | 25 |  |
| 36.AC unit automatic isolation valves | 23 | 23 | 23/25 | 23/25 | 21 |
| 37.Network Interface to BAS | 23 | 23 | 23 | 25 | 22 |
| Water Source Heat Pumps | | | | | |
| 38.AC unit including all controls | 23 | 23 | 23 | 25 |  |
| 39.Wall temperature sensor/thermostat | 23 | 23 | 23 | 25 |  |
| 40.HP unit automatic isolation valves | 23 | 23 | 23/25 | 23/25 | 21 |
| 41.Network Interface to BAS | 23 | 23 | 23 | 25 | 22 |
| VAV Packaged Air-Conditioning Systems | | | | | |
| 1. AC unit including all controls | 23 | 23 | 23 | 25 |  |
| 1. Network Interface to BAS | 23 | 23 | 23 | 25 | 22 |
| Variable-Refrigerant Flow Systems | | | | | |
| 1. VRF fan-coils and condensing unit including all factory mounted controls | 23 | 23 | 26 | 25 |  |
| 1. VRF thermostats and field mounted control devices | 23 | 25 | 25 | 25 |  |
| 1. Gateway to BAS | 23 | 25 | 25 | 25 | 22 |
| Laboratory HVAC Systems | | | | | |
| 1. Laboratory air valves, actuators, and controllers | 23 | 23 | 25 | 25 |  |
| 1. Snorkels with control dampers | 11/23 | 23 | 25 | 25 | 23 |
| 1. Fume hood monitors—constant volume hood | 11 | 11 | 26 | 25 |  |
| 1. Fume hood monitors—variable volume hood | 23 | 23 | 23 | 25 | 24 |
| 1. Fume hood sash position sensors | 23 | 23 | 25 | 25 |  |
| HVAC Terminal Boxes | | | | | |
| 1. Terminal box control transformer panel | 25 | 25 | 26/25 | 25 | 12, 25 |
| 1. Digital controller and damper actuator | 25 | 25 | 25 | 25 |  |
| 1. Airflow measurement transducer and piping | 25 | 25 | 25 | 25 |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1. Wall sensor module | 25 | 25 | 25 | 25 |  |
| 1. Terminal fan | 23 | 23 | 26 | 25 |  |
| 1. Electric reheat coil, including control transformer, safeties, and contactors | 23 | 23 | 26 | 25 | 26 |
| 2. HW control valve and actuator | 25 | 23 | 25 | 25 |  |
| Miscellaneous | | | | | |
| 1. Combination louver/dampers | 23 | 23 | 25 | 25 |  |

DIVISION KEY:

11 = Equipment

22 = Plumbing

23 = Heating, Ventilating, and Air Conditioning (HVAC)

25 = Integrated Automation

26 = Electrical

1. Wiring includes raceway, fittings, wire, boxes and related items, all voltages.
2. Wiring of damper actuator for HVAC system control, where indicated on HVAC drawings and smoke damper schedules, is specified under Division 25; wiring for fire/life safety control is specified under Division 26. Note that fire/life safety controller will require two contacts at these dampers to ensure that fire alarm control takes precedence over HVAC control.
3. Factory installed starters and variable-speed drives are specified under Division 23. Prewired control panel is specified under Division 23; single-point power connection (unless otherwise noted on drawings) is specified by Division 23.
4. Where drive is used for a life-safety system fan, wire input to drive to force drive to preset speed specified under Division 23; wiring to life-safety system is specified under Division 26.
5. Applies to motors that are not covered by Note 3. Integral starter control devices such as hand-off-auto (HAO) switches, 120V control transformers, and time- delay relays (from high to low speed) for two-speed motors are specified under Division 26.
6. Line voltage control devices, such as thermostats or switches, are specified under Division 25; wiring and conduit between control device and motor are specified under Division 26.
7. Factory installed and wired chilled and condenser water flow switches are specified under Division 23; no work is required under Division 25. Bidirectional (read/ write) factory-installed network interface between the BAS and chiller control panel is specified with chiller under Division 23; control wiring is specified under Division 25. Chiller vendor to provide all necessary technical assistance to the Division 25 contractor in mapping across chiller points to the BAS.
8. Fire and life-safety control systems, status devices (such as fan status switches and voltage-available relays), start/stop relays, and associated wiring and conduit are specified under Division 26. Identification of mechanical equipment termination contact locations by Division 23.
9. Emergency override switches, status lights and other refrigerant machinery room controls as required by mechanical code are specified under Division 25.
10. Unit heater and cabinet controls are specified under Division 23 and include thermostats and other controls, including control valves, all self-contained and factory mounted and wired. Wiring of remote wall-mounted thermostat on unit heaters, where shown on plans, is specified under Division 25. Unit heaters and cabinet heaters are not BAS controlled.
11. TDS controllers, bleed valves, injector pumps, make-up water flowmeters, and all other water treatment system controls are specified under Division 23. Field wiring of all components is specified under Division 25.
12. 120V power to BAS device control panels is specified under Division 26 for the panels shown on drawings. Power to all other control panels that may be required is specified under Division 25, coordinated with the Division 26 contractor for available circuits.
13. Lighting control vendor is to provide all necessary technical assistance to the Division 25 contractor in mapping across lighting control points to the BAS.
14. Power measuring sensors, installation, and wiring to a single central controller with network interface are specified under Division 26. Gateway and network connection from gateway to BAS are specified under Division 25. Power monitoring control vendor is to provide all necessary technical assistance to the Division 25 contractor in mapping across power monitoring control points to the BAS.
15. Generator monitoring sensors and central controller with gateway are specified under Division 26. Gateway and network connection from gateway to BAS are specified under Division 25. Generator vendor is to provide all necessary technical assistance to the Division 25 contractor in mapping across monitoring control points to the BAS.
16. Generator with skid fuel tank or day tank, including transfer pump and controls, is specified under Division 26. Main fuel tank with alarm and level sensors and associated fuel piping and venting is specified under Division 22. Remote fill station and piping to main fuel tank is specified under Division 22. Fuel-tank and fill-station alarm panels are specified under Division 22; connecting alarms to the BAS, including all conduit and wire for controls, is specified under Division 25. Power connections for fuel pumps and panel controls are specified under Division 26.
17. Hoods, including all required fire protection devices and integral listed balancing dampers, are specified under Division 11. Duct connection from hood collar to exhaust fan is specified under Division 23. Decorative duct enclosures to hide exhaust duct from view where required is specified under Division 11.
18. Providing and installing control dampers with actuators used for demand-controlled ventilation is specified under Division 11; control wiring is specified under Division 25.
19. Duct access doors required for access to control devices where required are specified under Division 23.
20. Actuators for motorized dampers supplied with fans or hoods where scheduled on HVAC drawings are specified under Division 23, mounted but not wired.
21. Automatic isolation valves for water-source heat pumps and water-cooled air conditioning are specified under Division 23 to be factory installed and wired where that is a standard option; if not, field installation is specified under Division 23, and field wiring is specified under Division 25.
22. Gateway to BAS is specified in Division 23, factory installed, with connection of gateway to BAS specified under Division 25. Air-conditioning vendor to provide all necessary technical assistance to the Division 25 contractor in mapping AC control points to the BAS.
23. Snorkel is specified under Division 11. Snorkel damper/air valve is specified under Division 23.
24. Hood manufacturer shall provide knockout on face for hood monitor.
25. Control transformers for terminal boxes shall be centralized in control panels specified under Division 25.
26. Factory-wired control transformer, safeties, and contactors with single-point power wiring connection are specified under Division 23.

## RELATED SECTIONS

* + 1. Drawings and general conditions of the contract, supplementary conditions, Division 01 specifications and general requirements are part of this specification and shall be used in conjunction with this section as part of the contract documents.
    2. The following sections constitute related work (based on CSI division numbering):
       1. Section 01xxx—Submittal Requirements
       2. Section 2305xx—Common Work Results for HVAC
       3. Section 2305xx—Testing, Adjusting, and Balancing
       4. Section 2308xx—Commissioning of HVAC
       5. Section 2330xx—HVAC Air Distribution
       6. Section 2350xx—Central Heating Equipment
       7. Section 2360xx—Central Cooling Equipment
       8. Section 2370xx—Central HVAC Equipment
       9. Section 2380xx—Decentralized HVAC Equipment
       10. Section 2500xx—Integrated Automation
       11. Section 2510xx—Integrated Automation Network Equipment
       12. Section 2530xx—Integrated Automation Instrumentation and Terminal Devices
       13. Section 2605xx—Common Work Results for Electrical
       14. Section 2608xx—Commissioning of Electrical Systems
       15. Section 2609xx—Instrumentation and Control for Electrical Systems
       16. Section 27xxxx—Communication
       17. Section 28xxxx—Security Access and Surveillance

## SCOPE OF WORK [SELECT ONE FROM 1.9 AND EDIT TO PROJECT SPECIFICS]

* + 1. Provide all labor and materials for complete, fully functioning control systems in accordance with contract documents.
    2. Submit qualification of project managers, engineers, programmers, field supervisors, and technicians to be assigned to this project with the solicitation response.
    3. Controls contractor’s labor shall include but shall not be limited to the following:
       1. Engineering services to size unscheduled valves and dampers based on design criteria and confirm sizing of scheduled valves and dampers
       2. Engineering services to produce requested submittals and working construction drawings and record drawings as specified here within
       3. Engineering services for required software programming
       4. Engineering services for graphics programming specified
       5. Engineering services for bench testing sequences and graphics in conjunction with owner representatives
       6. Control project management services as single point of contact to coordinate construction related control activities
       7. Field technicians for installation of control wiring and related control devices
       8. Field technicians to start, calibrate, adjust, and tune control loops
       9. Field technicians to perform system checkout and testing, and to complete required reports
       10. Field supervisor during controls installation and startup
       11. Field technicians to assist the mechanical contractor and testing, adjusting, and balancing (TAB) contractor in adjusting controls and determining set points related to TAB work
       12. Field representatives and/or classroom instructors to provide owner training as specified
       13. The mechanical contractor shall provide taps and other mechanical interfaces required for control equipment mounting into piping systems. The mechanical contractor shall install wells, and in-line mounted devices, such as valves, dampers, flowmeters, static pressure probes, etc., furnished by the controls contractor. The controls contractor shall be responsible for installation of other control devices, such as actuators, linkages, sensors, air terminal controllers, flow transducers, remote mounted control devices, control panels, control transformers, etc. It is the responsibility of the controls contractor and mechanical contractor to coordinate final assembly.
       14. Electrical work required as an integral part of control work is the responsibility of and under direction of the controls contractor
    4. The electrical contractor will provide circuit breakers, conduit, and wiring required to provide electrical power to controllers.
    5. The control contractor is responsible for providing final power connections to control devices from the appropriate electrical distribution.
    6. 120 to 24 VAC transformer panels shall be provided by the controls contractor and mounted adjacent to controller panels or locations found by the design and construction team and powered from dedicated electrical circuit.
    7. Should any change in number of controllers or addition of other electrical equipment after contracts are awarded, the controls contractor shall immediately notify the electrical contractor of the change. Additional costs due to these changes shall be the responsibility of the controls contractor.
    8. Coordinate with the electrical contractor for additional power requirements.
    9. BAS Ethernet network, including all hardware (routers, switches, firewalls, patch panels, patch cords, cabinets, etc.) is the responsibility of the owner.
    10. The cabling contractor, as provided by the controls contractor, shall provide all horizontal network cabling from device to IDF room and terminate to patch panel.
    11. The BAS Ethernet network shall employ network/data communications security requirements per NIST Special Publication 800-53, Revision 3, “Information Security.”
    12. The contractor shall be responsible to provide final locations of all necessary BAS data drops (from room patch panel to field jacks/patch panels) with the owner PM.
    13. Bench Testing (Vendor Site)
        1. Prior to any instance of installation, the bench testing shall include pretesting of all graphics, programmable logic, and mapped inputs and outputs to demonstrate compliance with the NFS standards and sequence of operations.
        2. Refer to third-party commissioning specifications (Section 01 91 10) and NFS Chapter 17 for additional requirements for field point-to-point verification, sensor calibration, and other prechecks after the controllers are energized.
        3. In addition to the commissioning scope indicated herein and in the individual System sections, the controls contractor shall work and cooperate fully with the owner’s third-party commissioning agent in demonstrating that the BAS is in compliance with the approved design.

## DESCRIPTION {WEB-BASED BAS INTERFACE REQUIREMENTS, EDIT TO PROJECT SPECIFICS}

* + 1. General. The control system shall consist of a high-speed, peer-to-peer network of DDC controllers and an operator workstation. The operator workstation shall provide for overall system supervision and configuration, graphical user interface, management report generation, and alarm annunciation.
    2. Performance Monitoring. The BAS will provide the specified performance monitoring functionality, including required monitoring points and performance metrics, improved through system accuracy, data acquisition and data management capabilities, and required graphical and data displays.
    3. Event Response. The BAS will provide the specified operational changes based on event response from the energy service provider.

## DESCRIPTION {FULL WEB-BASED INTERFACE WITH PERFORMANCE MONITORING AND EVENT RESPONSE, EDIT TO PROJECT SPECIFICS}

1. General. The control system shall consist of a high-speed, peer-to-peer network of DDC controllers, a control system server, and an operator workstation.
2. System software shall be based on a server/thin-client architecture and designed around the open standards of Web technology. The control system server shall be accessed using a web browser over the control system network, the owner’s local area network, and remotely over the Internet (through the owner’s LAN).
3. The intent of the thin-client architecture is to provide operators complete access to the control system via a web browser. No special software other than a Web browser shall be required to access graphics, point displays, and trends; configure trends; configure points and controllers; or edit programming.
4. Performance Monitoring. The BAS will provide the specified performance monitoring functionality, including required monitoring points and performance metrics, improved through system accuracy, data acquisition and data management capabilities, and required graphical and data displays.
5. Performance Standards. System shall conform to the following minimum standards over network connections:
   1. Graphic Display. A graphic with 20 dynamic points shall display with current data within ten seconds.
   2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within eight seconds.
   3. Object Command. Devices shall react to command of a binary object within two seconds. Devices shall begin reacting to command of an analog object within two seconds.
   4. Object Scan. Data used or displayed at a controller or workstation shall have been current within the previous six seconds.
   5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 45 seconds.
   6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every five seconds. Select execution times consistent with the mechanical process under control.
6. Performance. Programmable controllers shall be able to completely execute BAS PID control loops at a frequency adjustable down to once per second. Select execution times consistent with the mechanical process under control.
7. Multiple Alarm Annunciation. Each workstation on the network shall receive alarms within five seconds of other workstations.
8. Event Response. The BAS will provide the specified operational changes based on event response from the energy service provider.

## DESCRIPTION {A WEB-COMPATIBLE INTERFACE WITH PERFORMANCE MONITORING AND EVENT RESPONSE, EDIT TO PROJECT SPECIFICS}

1. General. The control system shall consist of a high-speed, peer-to-peer network of DDC controllers, a control system server, and/or an operator workstation.
2. The control system server and/or operator workstation shall provide for overall system supervision and configuration, graphical user interface, management report generation, and alarm annunciation.
3. The system shall support web browser access to the building data. A remote user using a standard web browser shall be able to access the control system graphics and change adjustable set points with the proper password.
4. Performance Monitoring. The BAS will provide the specified performance monitoring functionality, including required monitoring points and performance metrics, improved through system accuracy, data acquisition and data management capabilities, and required graphical and data displays.
5. Performance Standards. System shall conform to the following minimum standards over network connections:
   1. Graphic Display. A graphic with 20 dynamic points shall display with current data within ten seconds.
   2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within eight seconds.
   3. Object Command. Devices shall react to command of a binary object within two seconds. Devices shall begin reacting to command of an analog object within two seconds.
   4. Object Scan. Data used or displayed at a controller or workstation shall have been current within the previous six seconds.
   5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 45 seconds.
   6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every five seconds. Select execution times consistent with the mechanical process under control.
6. Performance. Programmable controllers shall be able to completely execute BAS PID control loops at a frequency adjustable down to once per second. Select execution times consistent with the mechanical process under control.
7. Multiple Alarm Annunciation. Each workstation on the network shall receive alarms within five seconds of other workstations.
8. Event Response. The BAS will provide the specified operational changes based on event response from the energy service provider.

## APPROVED CONTROL SYSTEM PRIMARY MANUFACTURERS

* + 1. The following are approved BAS manufacturers and product lines:

|  |  |
| --- | --- |
| Manufacturer | Product Line |
| Manufacturer A |  |
| Manufacturer B |  |
| Manufacturer C |  |

Note:

1. The order of the above list of manufacturers does not indicate preference. Inclusion on this list does not guarantee acceptance of products or installation. BASs shall comply with the terms of this specification.
2. Use operator workstation software, controller software, custom application programming language, building controllers, custom application controllers, and application-specific controllers only from one of the manufacturers and product lines listed.
3. Other products specified herein (such as sensors, valves, dampers, and actuators) need not be manufactured by the above manufacturers.

## QUALITY ASSURANCE

* + 1. Installer and Manufacturer Qualifications
       1. Installer shall have an established working relationship with BAS manufacturer of not less than three years.
       2. Installer shall have successfully completed BAS manufacturer’s control system training. Upon request, installer shall present certification of completed training including hours of instruction and course outlines.
    2. The BAS shall be engineered, installed, started/calibrated, and serviced by the manufacturer’s authorized local representative. All personnel shall be factory trained with a minimum of three years’ experience in the installation and maintenance of BAS and HVAC systems similar in size and complexity to owner’s BAS. The manufacturer shall also have a maintenance service center operating 24/7 within 50 miles of the owner. The service center shall have technical staff, spare parts inventory, and necessary test and diagnostic equipment and ability to bench test controllers prior to installing in the field.
    3. The controls contractor shall have at least two full-time journeyman employees who are certified and proficient in installing and programing the provided equipment with relevant project experience at the time of bid and contract award. One of these employees must be included in a project staffing plan and assigned to the project upon award for its duration. Controls contractor is to provide resumes for all staff members included in the project staffing plan. Resumes are to include years in trade and relevant project examples for each staff member.
    4. All BAS controllers shall be BACnet Testing Laboratories (BTL) certified.
    5. Materials and equipment shall be the cataloged products of manufacturers regularly engaged in production and installation of automatic environmental control systems and shall be the manufacturer’s latest standard design that complies with these specification requirements.
    6. All systems, equipment, components, accessories, software, and installation hardware must be new, free from defects, and currently in production. All product shall support equipment replacement for ten years.
    7. Provide the same manufacturer components of a given type product throughout the project.
    8. Install and operationally check systems utilizing factory-trained competent technicians skilled in the setting and adjustment of equipment used in this project.
    9. Test, adjust, and calibrate all end-to-end instruments prior to commissioning
    10. Install devices in appropriate enclosure and in an accessible location.
    11. Install systems and devices in a neat, workmanlike manner and in accordance with manufacturer's recommendations.
    12. Continually monitor the field installation for code compliance and quality workmanship.
    13. Remove and reinstall any systems or devices where installation does not meet project intent or required level of quality.
    14. Comply with all health and safety regulations.
    15. Include automatic restart logic for all controllers due to loss of power, safeties, fire alarm shutdown, etc.
    16. Electrical components, devices, and accessories are to be listed and labeled as defined in CEC (NFPA 70), Article 100 by a testing agency acceptable to the owner representative and marked for intended use.

## QUALITY ASSURANCE PROGRAM

* + 1. The controls contractor shall implement a quality assurance program. At minimum, this program shall consist of the following requirements:
       1. The controls contractor shall assign a single individual to serve as the quality assurance manager, who is to be responsible for management of the program.
       2. The quality assurance manager shall provide or maintain the following:
          1. Documentation of training for employees, including office, field, and subcontractors, on the quality assurance program.
          2. Written verification that each worker on the project has read the specification sections outlining the project requirements for his or her area of specialty. The initial project team shall be documented in the first project submittal.
          3. A detailed audit trail for all quality assurance issues: problem ID number, date of original problem report, name of individual initiating report, and individual assigned responsibility for resolving the problem.
          4. Audit trail of firmware and software versioning and archive of the files.
       3. Each individual team member shall be responsible for identifying and reporting quality assurance problems and for assisting, as requested by the quality assurance manager, in the resolution thereof.
       4. Installer Qualifications: The automatic control system manufacturer’s authorized representative who is trained and approved for installation of system components required for this project.
       5. Equipment, devices, and materials shall be immune to electromagnetic interferences and shall conform to all performance requirements of’ the specifications when exposed to the following interferences:
          1. Project lighting, telephone, and elevator equipment
          2. AM signals as generated from transmitters
          3. VHF and UHF signals as generated by external or internal portable or fixed transmitters
          4. Electrical noise on the building power system, both spurious and harmonies
          5. The installations shall not radiate signals that cause interference that hinder the correct operation of the owner’s on-site equipment.
    2. The BAS and all individual electrical equipment, devices, and components shall comply with the requirements of the Federal Communication Commission (FCC) rules and regulations Part 15, sub part J and all other applicable codes and statutes with respect to the radiation and conduction of radio frequency interference.

## INTEGRATION REQUIREMENTS

* + 1. The BAS shall provide integrations services and coordinate with other trades and service providers as described in other sections of this specification.
    2. Contractor is responsible for IP drops as shown in the HVAC component of the BAS infrastructure plan.
    3. Electrical is responsible for providing conduit and pullwire for all BAS IP cables.
    4. Electrical is responsible for the identification of the conduit per the contract documents.
    5. The BAS IP cable should have its own unique color.
    6. Cabling trade is responsible for pulling cable and for providing an RJ-45 data drop for all BAS IP cables. See cabling infrastructure plans and specifications for details. Terminate at the patch panel.
    7. Owner is responsible for terminations from the patch panel to the BAS switch.
    8. BAS contractor is responsible the integration of the data points from this subsystem as outlined in the BAS infrastructure plan. BAS contractor is responsible for supplying and installing all of the IP devices covered in the BAS infrastructure plan.
    9. BAS contractor is responsible for networking all the non-IP devices identified in the BAS infrastructure plan.
    10. Mechanical contractor is responsible for supplying, installing, and running network connections between the boiler plant controller and the three boilers.
    11. See responsibility matrix for requirements by trade
    12. Integration scope for each system shall be as outlined below.
        1. Air-handling units (AHUs)
           1. The BAS contractor is responsible for mapping the points listed in the equipment schedule for VFDs, airflow stations, and the special use areas—e.g., data center cooling system point shown on the integration points list.
           2. The BAS contractor is responsible for providing the necessary controls for AHUs and other equipment shown in the BAS scope of work.
           3. The BAS contractor is responsible for trends and alarms for point identified as requiring trends and alarms in the point’s integration list.
           4. HVAC scheduling by the BAS contractor:

The BAS contractor is responsible for implementing the IECC or California Title 24 HVAC standby requirements as found in the lighting system integration sequence of operations.

ASHRAE Guideline 36 requirements govern the sequences of operation for the AHUs.

Trim and respond reset logic

* + - * 1. The BAS contractor is responsible for creating floor plan and equipment graphics for the HVAC component devices as specified in the BAS specification.
        2. The BAS contractor is responsible for tracking energy and power consumption from the VFDs and current transducers s using the energy metering system*.*
        3. The BAS contractor and the HVAC system contractor shall jointly commission the HVAC devices to be integrated into the BAS.
      1. Chiller Plant
         1. The BAS contractor is responsible for mapping the points listed in the equipment schedule for VFDs, chillers, pumps, cooling towers (if applicable), refrigeration monitoring and alarm system, and the chemical treatment system shown on the integration points list.
         2. The BAS contractor is responsible for providing the necessary controls for the chiller components and other equipment shown in the BAS scope of work.
         3. The BAS contractor is responsible for trends and alarms for point identified as requiring trends and alarms in the point’s integration list.
         4. HVAC scheduling by the BAS contractor.

The BAS contractor is responsible for implementing the IECC or California Title 24 schedule requirements as applicable.

ASHRAE Guideline 36 requirements govern the sequences of operation.

* + - * 1. The BAS contractor is responsible for creating floor plan and equipment graphics for the HVAC component devices as specified in the BAS specification.
        2. The BAS contractor is responsible for tracking energy and power consumption from the VFDs and the chillers using the energy metering system. (***Note:*** Provide a complete list c/w the points to be monitored.)
        3. The BAS contractor and the HVAC system contractor shall jointly commission the HVAC devices to be integrated into the BAS.
      1. Boiler Plant
         1. The BAS contractor is responsible for mapping the points listed in the equipment schedule, including boilers, VFDs, pumps, condensate recovery systems, deaerator, water treatment, etc. shown on the integration points list.
         2. The BAS contractor is responsible for providing the necessary controls for the boiler components and other equipment shown in the BAS scope of work.
         3. The BAS contractor is responsible for trends and alarms for point identified as requiring trends and alarms in the point’s integration list.
         4. HVAC scheduling by the BAS contractor.

The BAS contractor is responsible for implementing the IECC or California Title 24 requirements.

ASHRAE Guideline 36 requirements govern the sequences of operation.

Trim and respond reset logic

* + - * 1. The BAS contractor is responsible for creating floor plan and equipment graphics for the HVAC component devices as specified in the BAS specification.
        2. The BAS contractor is responsible for tracking energy and power consumption from the VFDs and the boilers using the energy metering system.
        3. The BAS contractor and the HVAC system contractor shall jointly commission the HVAC devices to be integrated into the BAS.
      1. IDF Room HVAC
         1. The BAS contractor is responsible for mapping the points listed in the IDF room HVAC system shown on the integration points list.
         2. The BAS contractor is responsible for providing the necessary controls for the IDF room HVAC components and other equipment shown in the BAS scope of work.
         3. The BAS contractor is responsible for trends and alarms for point identified as requiring trends and alarms in the point’s integration list.
         4. HVAC scheduling by the BAS contractor:

The BAS contractor is responsible for implementing the IECC or California Title 24 requirements.

ASHRAE Guideline 36 requirements govern the sequences of operation.

* + - * 1. The BAS contractor is responsible for creating floor plan and equipment graphics for the HVAC component devices as specified in the BAS specification.
        2. The BAS contractor is responsible for tracking energy and power consumption from this system using the energy metering system.
      1. Miscellaneous Heating and Exhaust System Devices
         1. The BAS contractor is responsible for mapping the points listed in the VFDs and boilers shown on the integration points list.
         2. The BAS contractor is responsible for providing the necessary controls for the unit heaters, cabinet unit heaters, exhaust fans, and other equipment shown in the BAS scope of work.
         3. The BAS contractor is responsible for trends and alarms for points identified as requiring trends and alarms in the point’s integration list.
         4. HVAC scheduling by the BAS contractor.
         5. The BAS contractor is responsible for creating floor plan and equipment graphics for the HVAC component devices as specified in the BAS specification.
         6. The BAS contractor is responsible for tracking energy and power consumption from the VFDs and the boilers using the energy metering system.
         7. The energy monitoring requirement for these systems is limited to calculating kilowatts and kilowatt-hours for the motor(s) identified as requiring this in the points list.
         8. The BAS contractor and the HVAC system contractor shall jointly commission the HVAC devices to be integrated into the BAS.
         9. The BAS contractor and the HVAC system contractor shall jointly commission the HVAC devices to be integrated into the BAS.
    1. The following section utilizes the ASHRAE Guideline 13 4-Tier architecture model.
       1. Integration to Tier 2 Lighting Subsystem
          1. The BAS contractor is responsible for mapping the lighting points listed in the lighting System point’s integration list.
          2. There are no hardwired points by the BAS contractor. All points come via the integration.
          3. The BAS contractor is responsible for trends and alarms for point identified as requiring rends and alarms in the lighting system point’s integration list.
          4. Lighting system scheduling is done through the lighting system front end software application.
          5. The BAS contractor is responsible for implementing the California Title 24 HVAC standby requirements as found in the lighting system integration sequence of operations.
          6. The BAS contractor is responsible for creating floor plan and equipment graphics as specified in the BAS specification.
          7. The BAS contractor is responsible for tracking energy and power consumption from the lighting system using the energy metering system.
          8. The BAS contractor and the lighting system contractor shall jointly commission the lighting system points to be integrated into the BAS.
          9. Contractor is responsible for IP drops as shown in the lighting component of the BAS infrastructure plan.
          10. Electrical is responsible for providing conduit and pullwire for all BAS IP cables.
          11. Electrical is responsible for the identification of the conduit per the contract documents.
          12. The BAS IP cable should have its own unique color. (Note: BAS designer needs to choose a color that is unique so it can be easily identified.)
          13. Cabling trade is responsible for pulling cable and for providing an RJ-45 data drop for all BAS IP cables. See cabling infrastructure plans and specifications for details. Terminate at the patch panel.
          14. Owner is responsible for terminations from the patch panel to the BAS switch.
          15. BAS contractor is responsible the integration of the data points from this subsystem as outlined in the BAS infrastructure plan. BAS contractor is responsible for supplying and installing all of the IP devices covered in the BAS infrastructure plan.
          16. BAS contractor is not responsible for any networking of the non-IP devices needed for this system.
          17. Mechanical contractor is responsible for supplying, installing, and running network connections between the boiler plant controller and the three boilers.
          18. See responsibility matrix for requirements by trade.
       2. Integration to Tier 2 Fire Subsystem
          1. The BAS contractor is responsible for mapping the fire alarm system points listed in the ire alarm system point’s integration list.
          2. There are no hardwired points by the BAS contractor. All points come via integration.
          3. The BAS contractor is responsible for trends and alarms for points identified as requiring trends and alarms in the lighting system point’s integration list.
          4. There is no requirement for scheduling.
          5. All communication is in one direction from the fire alarm system to the BAS front end. The BAS front end has read-only access as the BAS is a non UL-listed system.
          6. The BAS contractor is responsible for creating floor plan and equipment graphics as specified in the BAS specification.
          7. There is no energy monitoring requirement for this systems.
          8. When a fire/smoke occurs, the fire controller shall toggle the fire alarm point to the BAS that an event has occurred. Fire/smoke controls are by the electrical designer. The BAS shall just report that the fire/smoke event has occurred. This shall be treated as a critical alarm.
          9. The BAS contractor and the fire alarm contractor shall jointly commission the lighting system points to be integrated into the BAS.
          10. Contractor is responsible for IP drops as shown in the fire alarm component of the BAS infrastructure plan.
          11. Electrical is responsible for providing conduit and pullwire for all BAS IP cables.
          12. Electrical is responsible for the identification of the conduit per the contract documents.
          13. The BAS IP cable should have its own unique color. (Note: BAS designer needs to choose a color that is unique so it can be easily identified.)
          14. Cabling trade is responsible for pulling cable and for providing an RJ-45 data drop for all BAS IP cables. See cabling infrastructure plans and specifications for details. Terminate at the patch panel.
          15. Owner is responsible for terminations from the patch panel to the BAS switch.
          16. BAS contractor is responsible the integration of the data points from this subsystem as outlined in the BAS infrastructure plan. BAS contractor is responsible for supplying and installing all of the IP devices covered in the BAS infrastructure plan.
          17. BAS contractor is not responsible for any networking of the non-IP devices needed for this system.
          18. See responsibility matrix for requirements by trade.
       3. Integration to Tier 2 Gas Detection Subsystem
          1. The BAS contractor is responsible for mapping the gas detection system points listed in the two gas detection systems point’s integration list.
          2. There are hardwired points by the BAS contractor.
          3. The BAS contractor is responsible for trends and alarms for points identified as requiring trends and alarms in the system point’s integration list.
          4. There is no requirement for scheduling.
          5. All communications is in one direction from the gas detection system to the BAS front end. This is to ensure that there is a single source of responsibility for this system.
          6. The BAS contractor is responsible for creating floor plan and equipment graphics as specified in the BAS specification.
          7. The energy monitoring requirement for these systems are limited to calculating kilowatts and kilowatt-hours for the exhaust fan(s).
          8. When a gas detection event occurs, the controller shall report the event to the BAS. This shall be treated as a critical alarm.
          9. The BAS contractor and the gas detection system equipment supplier shall jointly commission the system points to be integrated into the BAS.
          10. Contractor is responsible for IP drops as shown in the gas detection subsystem component of the BAS infrastructure plan.
          11. Electrical is responsible for providing conduit and pullwire for all BAS IP cables.
          12. Cabling trade is responsible for pulling cable and for providing an RJ-45 data drop for all BAS IP cables. See cabling infrastructure plans and specifications for details. Terminate at the patch panel. Owner is responsible for terminations from the patch panel to the BAS switch.
          13. BAS contractor is responsible the integration of the data points from this subsystem as outlined in the BAS infrastructure plan. BAS contractor is responsible for supplying and installing all of the IP devices covered in the BAS infrastructure plan.
          14. BAS contractor is responsible for networking all the non-IP devices identified in the BAS infrastructure plan.
          15. Mechanical contractor is responsible for supplying and installing the equipment.
          16. All low-voltage wiring and network is by the BAS contractor.
          17. See responsibility matrix for requirements by trade.
       4. Integration to Tier 2 Energy Metering Subsystem
          1. Electrical is responsible for providing power to the water meter pulse heat.
          2. BAS contractor is responsible for collecting the pulse head data from the water meter to calculate the daily water consumption for the building as a whole and the cooling tower.
          3. BAS contractor is responsible for networking all the non-IP devices identified in the BAS infrastructure plan.
          4. Mechanical contractor is responsible for supplying and installing the water meter with the pulse head.
          5. All low-voltage wiring and network is by the BAS contractor.
          6. Contractor is responsible for a non-IP network connection to the building electrical meter as shown in the energy metering subsystem component of the BAS infrastructure plan.
          7. Electrical is responsible for providing conduit and pullwire for all BAS IP cables.
          8. Cabling trade is responsible for pulling cable and for providing an RJ-45 data drop for BAS IP cable. See cabling infrastructure plans and specifications for details. Terminate at the patch panel. Owner is responsible for terminations from the patch panel to the BAS switch.
          9. BAS contractor is responsible the integration of the electrical meter data points from the VFDs, boilers and chillers, and other devices identified as having kilowatt and kilowatt-hour data available for equipment level electrical monitoring. BAS contractor is responsible for supplying and installing all of the IP devices covered in the BAS infrastructure plan.
          10. BAS contractor is responsible for collecting the amp data from any current transducers supplied and installed in the work and for then calculating the kilowatts and kilowatt-hours from the current transducer for that piece of equipment.
          11. BAS contractor is responsible for networking all the non-IP devices identified in the BAS infrastructure plan.
          12. Mechanical contractor is responsible for supplying and installing the gas meter temperature compensated pulse head.
          13. All low-voltage wiring and network is by the BAS contractor.
          14. See responsibility matrix for requirements by trade.
       5. Integration to Tier 2 Water Metering Subsystem
          1. Electrical is responsible for providing power to the water meter pulse head.
          2. BAS contractor is responsible for collecting the pulse head data from the water meter to calculate the daily water consumption for the building as a whole and the cooling tower.
          3. Mechanical contractor is responsible for supplying and installing the water meter with the pulse head.
          4. All low-voltage wiring and network is by the BAS contractor.
          5. See responsibility matrix for requirements by trade.
       6. Non-IP Network Devices Devices
          1. BAS contractor is responsible for all non-IP network wiring excluding the boiler plant controller wiring, which is the responsibility of the mechanical contractor to provide.
          2. If the boilers operate on a peer-to-peer basis without the need for a boiler plant controller and only require a network connection to each boiler, then this work is by the BAS contractor.
          3. See Sections 2.21 for wiring details.
          4. See Informative Appendix F for sources of specification information for the proposed open protocol used in this project.
          5. See responsibility matrix for requirements by trade.
          6. BAS contractor is responsible for completing the VM requirements document in this specification and submitting it as a submittal so the owner’s IT department can set up the VM for the BAS contractor to install the front-end client software application.
          7. The security requirements of this project require that a Tier 2 device with embedded graphics capability be provided for the data center component of the HVAC subsystem.
          8. See responsibility matrix for requirements by trade.

## SUBMITTALS

* + 1. Specification Compliance
       1. An electronic copy of the specification will be provided to the vendor. Vendor shall indicate one of the following on every specification requirement paragraph by paragraph:
       2. Comply—Vendor complies or exceeds this requirement.
       3. Deviation—Vendor deviated from this requirement but provides similar operational and functional capability. Vendor to describe the deviation and how its product meets the specification performance requirement.
       4. Noncompliant—Vendor’s proposed product does not meet the specification requirement.
    2. All submittals, record documents, operations manuals should be indexed. PDF documents should include searchable text. Scanned documents are not acceptable. Provide the following submittals with a minimum drawing size of 11 x 17:
       1. Nodes—Each TCP/IP node shall include:
          1. Device description
          2. Device name
          3. BACnet instances (coordination with owner required)
          4. Physical location (room number or location description)
          5. Dedicated I/O locations
       2. System control drawings
          1. Schematic system diagrams
          2. Instrumentation with point name, range, and address
          3. Low-voltage power wiring controls

Submit data concerning type of power wiring and installation methods, including raceway types and grounding methods.

Perform voltage drop calculations for all low-voltage DDC circuits. Voltage drop to include number of devices and wiring run lengths, calculated voltage available at each device.

Submit diagram of power wiring layout.

* + - * 1. Controls wiring for MS/TP or Modbus RTU networks

Submit data concerning type of signal wiring and installation methods, including raceway types and grounding methods.

Perform voltage drop calculations for all low-voltage DDC circuits. Voltage drop to include number of devices and wiring run lengths, calculated voltage available at each device.

Submit diagram of network layout.

* + - * 1. Sequence of operation
        2. Bill of material
      1. Detailed controller layout and wiring drawings points list I/O spreadsheet
         1. Point name
         2. Type
         3. Description
         4. Function
         5. Address
         6. Signal (input or output)
         7. Device range
         8. Engineering units
      2. Controller spreadsheet
         1. Model number
         2. Firmware revision
         3. License information
         4. Physical location where deviates from mechanical plan (room number or location description)
      3. Sequences of operations (SOO)
         1. Include sequences based on the SOO provided by the engineer of record.
         2. Sequences for large, special function rooms shall be provided by the owner. Controls contractor to submit specific details regarding sensor selection, quantity, location to properly support a control strategy that meets the requirements of the space.
      4. Software and firmware operational documentation:
         1. Software operating and upgrade manuals
         2. Program software backup on a USB complete with data files
         3. Device address list
         4. Printout of software application and graphic screens
         5. Software license required by and installed for BAS workstations and control systems
      5. Shop drawings
         1. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, sensing devices, safety devices, and control devices
         2. Wiring diagrams, including power, signal, and control wiring. Differentiate between manufacturer-installed and field-installed wiring.
         3. Details of control panel faces, including controls, instruments, and labeling
         4. Written description per controller with all the time-delay and additional programming details of functionality to properly program the SOO
         5. Wire sheet of programming from written SOO
         6. Schedule of dampers provided by BAS contractor including size, leakage, and flow characteristics
         7. Schedule of valves, including size, type, leakage, and flow characteristics
         8. Network diagram: Detail network design showing control composite with controllers, subsystems, interface equipment, gateways and showing connection method to controlled and monitored systems and equipment. Diagram shall give an overview of work to be performed and shall indicate which discipline shall be responsible for providing hardware necessary to integrate subsystem control systems.
         9. Trunk cable schematic showing programmable control unit locations and trunk data conductors
         10. Full points list of connected data points, including connected control unit and network input devices
         11. Coordination and submission of Division 23 equipment final points list for third-party integrated devices is the responsibility of the BAS provider and should be included in BAS submittal package for coordination and review by owner. Refer to BAS design drawing details for additional project specific data points.
         12. Alarm matrix showing points alarmed, priority, and notification lists
         13. Point naming convention database describing unique names that will be programmed for I/O points and critical internal control variable point that conforms to owner’s standard naming convention. For each point, note which points will be overridable for commissioning testing and from the front-end operator workstation.
         14. System graphics indicating monitored systems, data (connected and calculated) point addresses, and operator notations
         15. System configuration showing peripheral devices, batteries, power supplies, diagrams, and interconnections
      6. Field test reports: Indicate and interpret test results for compliance with performance requirements.
      7. Provide the following maintenance data for systems to be included in maintenance manuals:
         1. Maintenance instructions and lists of spare parts for each type of control device, electronic control cabinet
         2. Interconnection wiring diagrams with identified and numbered system components and devices
         3. Keyboard illustrations and step-by-step procedures indexed for each operator function
         4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances
         5. Calibration records and list of set points
         6. Qualification data for firms and persons specified in Article 1.11, “Quality Assurance”
      8. Project record documents: Record actual locations of control components, including control units, thermostats, and sensors. Revise shop drawings to reflect actual installation and operating sequences and set points established during commissioning.
      9. Product Data for each product submission shall include the following:
         1. Table of contents for each submission
         2. Construction details, material descriptions, dimensions of individual components and profiles, and finishes
         3. BACnet points list for all controllers detailing the description, function, address, and specific naming of each point so that it may be identified upon discovery during integration to the optimization server database. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
         4. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity
         5. Product description with complete technical data, performance curves, and product specification sheets
         6. When a manufacturer’s data sheet refers to a series of devices rather than a specific model, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Data sheets shall include sufficient technical data to describe instrument parameters required as specified.
         7. Installation, operation, and maintenance instructions, including factors effecting performance
         8. Bill of materials indicating quantity, manufacturer, and extended model number for each unique product
         9. When manufacturer's product datasheets apply to a product series instead of a specific product model, clearly indicate, and mark only applicable information. Do not use highlighting pens, as the marks often photocopy or scan as black and become unreadable.
         10. Each submitted piece of product literature shall clearly cross-reference specification and drawings that submittal is to cover.
      10. Completion Checklist:
          1. Submit with shop drawings and detailed completion checklist, including written procedures for adjusting and calibrating each type of instrument and sensor. Engineer reserves the right to request modifications to any procedure that is incomplete inadequate to prove system performance.
          2. Checklist shall include references to the following additional requirements:

Controls contractor and mechanical contractor shall walk proposed static pressure sensor and flowmeter locations and mark up drawings for review and approval by owner and engineer prior to installation.

Instruments and sensors shall be calibrated by comparison to known device that is traceable to National Institute of Standards and Technology.

Each point shall be checked for calibration, connection to correct control loop, and proper setting of limit and alarm values.

Transducers and other output devices shall be properly zeroed and calibrated at both minimum and maximum output. Document settings for discrete instruments and set points for analog instruments shall include minimum and maximum positions for safe operating conditions where applicable (max. pump speed or max. frequency of fan drive, etc.).

Control loops shall be tuned to maintain controlled process variable at set point through seasonal conditions without operator intervention. Provide multiple sets of tuning parameters if necessary. Controller shall automatically use tuning parameters appropriate to existing ambient conditions. Maintain record on completion checklist

of control loops that require tuning at alternate times of year. Instruct technicians to supply default parameters that can approximate stable control until actual load conditions allow proper tuning of control loops.

Performance tests of analog control loops shall be performed by changing set points and verifying that sequences can come into stable control within a reasonable time period appropriate for each sequence. Simulate load changes for pressure and flow control loops.

Performance tests of discrete control loops shall be performed by adjusting set point and verifying sequence action.

Alarms, including network failures, shall be tested for each controller and device connected to network. Ensure that alarms may be properly acknowledged.

Schedules for each system/device shall be verified.

Graphics shall be verified for functionality including password protection, floor plan displays, system displays, alarm messaging, historical trends, report generation and HVAC schedules.

Testing of BAS to ensure cyber security. Coordinate testing requirements with owner.

## OPERATION AND MAINTENANCE MANUALS

* + 1. Refer to Division 01, “General Requirements.”
    2. Operation and maintenance (O&M) manuals shall provide descriptions of maintenance on all system components, including sensors and controlled devices. All information shall be accessible through the graphical user interface. Descriptions shall include the following:
       1. Product manuals for key software tasks.
          1. Operating the system

Installation manuals

Software programming manuals

Configuration manuals

Equipment datasheets

Approved submittals

As-built drawings

As-built sequences

Final point-to-point checklist

Programming printout wire sheet (hard and soft copy)

* + - * 1. Administering the system
        2. Application programming
        3. Engineering the network
        4. Setting up the Web server
        5. Report creation
        6. Graphics creation
        7. Data backup and Archiving
      1. List of recommended maintenance tasks associated with the system, controllers, instruments, Web servers, and Web clients
         1. Define the task.
         2. Recommend a frequency for the task.
         3. Reference the product manual that includes instructions on executing the task.
      2. Licenses, guarantees, and warranty documents for equipment and systems.
      3. System architecture diagram for components within the building annotated with specific location information.
      4. As-built drawing for each control panel
      5. As-built wiring design diagram for each control panel
      6. As-built system flow diagram for each system
      7. Sequence of control for each system
      8. Product data sheet for each component
      9. Troubleshooting guide
      10. Repair parts list
      11. Calibration instructions
      12. Control contractor’s completion checklist
      13. Manufacturer representative's name, address, and phone number

## RECORD DRAWINGS

* + 1. Refer to Division 01, “General Requirements.”
    2. Submit revised shop drawings indicating changes made during project.
    3. Record drawing submittals shall be inclusive of BAS as installed and commissioned.
    4. Update control diagrams to include tuning parameters and set points applicable to systems depicted as of date of system completion. This information shall be incorporated with the sequence of operation for each system.
    5. Include floor plans showing location of control panels and routing of BAS network and cabling.
    6. Provide passwords, if used, for back-up, and restore functions for each controller.
    7. All administrator passwords for the system, including operation, system management, database management, and device programming must be identified and submitted to the owner.

## WARRANTY

* + 1. Warranty period shall begin as authorized by the owner's representative in writing. Authorization will not be given before the following conditions are met:
       1. All verified completion checklists provided to owner
       2. Completion of all punch list items
       3. Conduction of a preliminary training session for personnel. The training shall consist of an orientation session at the job site to familiarize the personnel with the location and type of controlled equipment and controls on the project, a discussion of the control sequences, and a review of the control drawings.
       4. Completion and distribution of the as-built control drawings, including correction of all items noted by owner and engineer after review of the documents.
    2. Prior to the beginning of the warranty period, provide a vendor warranty certificate that includes the following:
       1. Warranty issue management practices overview, including issue tracking policies
       2. Warranty begin and end dates
       3. Twenty-four-hour dispatch phone number
       4. Service request e-mail address
       5. Service personnel names and cell phone numbers
       6. Authorized service manager for scheduled repair commitments
    3. Provide all services, installation, materials, and equipment necessary for the successful operation of the project BAS for a period of three (3) years upon issuance of the project’s Certificate of Substantial Completion. This warranty is in addition to the warranty and defective work requirements of the contract documents.
    4. Warranty shall cover all costs for parts, labor, associated travel, and expenses.
    5. This warranty shall apply equally to both hardware and software.
    6. Sequence of operation programming issues due to misinterpretations, sequence program errors, or deviations from a system’s original or formally changed operation shall be corrected at no additional cost to the owner.
    7. Hidden or assumed conditions that initially appear correct but are later found to be defective or incorrect shall be rectified to their proper state or purpose.
    8. Coordinate with the owner representative to continuously correct all deficiencies discovered by owner during normal occupied building operation. This shall not be counted as training time.
    9. Scheduled inspections:
       1. Two inspections shall be performed prior to warranty expiration, and all work required shall be performed. Inspections shall be scheduled six (6) months after owner acceptance and one (1) month prior to end of warranty period.
       2. These inspections shall include the following:
          1. Visual checks and operational tests of equipment
          2. Clean control system equipment including interior and exterior surfaces
          3. Check and calibrate each field device. Check and calibrate 50% of the total analog inputs and outputs during the first inspection. Check and calibrate the remaining 50% of the analog inputs and outputs during the second major inspection. Certify analog test instrumentation accuracy to be twice the specified accuracy of the device being calibrated. Randomly check at least 25% of all digital inputs and outputs for proper operation during the first inspection. Randomly check at least 25% of the remaining digital inputs and outputs during the second inspection.
          4. Run system software diagnostics and correct diagnosed problems.
          5. Resolve any previous outstanding problems.
    10. Two (2) months prior to the warranty expiration date, provide all program upgrades available from the manufacturer, including software revisions, controller firmware revisions, and security patches. At the expiration of the warranty period, all software and firmware shall be the manufacturer’s latest stable release of market products.
    11. An owner request for a controls contractor warranty service response shall be on a 24/7 basis. Provide a service request acceptance acknowledgment within one hour.
    12. Nonemergency service shall be provided within two business days of receiving an acceptance notification. Furnish telephone numbers and e-mail address where service representatives can be reached during normal business hours. Service personnel shall be at the site the next business day after receiving a request for service.
    13. Emergency service shall be provided within two hours after receiving an acceptance notification. Furnish telephone numbers and e-mail address where service representatives can be reached. Service personnel shall be at the site within 24 hours of receiving a request for service.
    14. Owner will maintain a log of warranty issues. The owner log will be the master project record used to resolve open warranty items.
    15. During the warranty period, the contractor shall maintain a backup of all software installed in the system. The backup shall be updated monthly or whenever the contractor makes a change to the software. A reload of backup software onto the system shall be performed by the contractor immediately upon notification by the owner. The reload shall be free of charge.
    16. At the end of the warranty period, the contractor shall provide updated copies of the latest versions of all project record documentation, including final updated drawings, software documentation, and electronic media backups that include all changes that have been made to the system during the warranty period.
    17. Warranty period shall be three (3) years after the Impact Management Platform (IMP) project completion.

## DELIVERY, STORAGE, AND HANDLING

* + 1. Deliver equipment after specified environmental conditions have been permanently established in spaces where equipment is to be placed.
    2. Store equipment in spaces with environments controlled within the manufacturer’s ambient temperature and humidity tolerances for nonoperating equipment.
    3. 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 unit manufacturer.

## OWNERSHIP OF PROPRIETARY MATERIAL

* + 1. Owner shall retain all rights to software for this project.
    2. All project-developed software, files, and documentation shall become the property of owner. These include but are not limited to the following:
       1. Control sequences
       2. Customized programming
       3. Contract drawings and specifications
       4. Control drawings
       5. Virtual server and workstation software
       6. Application programming tools
       7. Configuration tools
       8. Addressing tools
       9. Application files
       10. Configuration files
       11. Graphic files
       12. Report files
       13. Graphic symbol libraries
       14. All documentation

# PRODUCTS

## SECTION INCLUDES

* + 1. Materials
    2. Communication
    3. Operator Interface
    4. Controller Software details
    5. Building Controllers
    6. Custom Application Controllers
    7. Application-Specific Controllers
    8. Input/Output Interface
    9. Power Supplies and Line Filtering
    10. Auxiliary Control Devices
    11. Wiring and Raceways
    12. Fiber-Optic Cable System
    13. Compressed Air Supply—Pneumatic

## MATERIALS

* + 1. Use new products that the manufacturer is currently manufacturing and that have been installed in a minimum of 25 installations. Do not use this installation as a product test site unless explicitly approved in writing by the owner or the owner’s representative. Spare parts shall be available for at least five years after completion of this contract.

## COMMUNICATION

* + 1. Control products, communication media, connectors, repeaters, hubs, and routers shall compose an open protocol BAS. Controller and operator interface communication shall conform to

{open-protocol body} conformance and/or certification requirements.

* + 1. Each controller on the riser diagram requiring IP communications shall come with a CAT 5 or CAT 6e port.
    2. Project drawings should indicate remote buildings or sites to be connected to the enterprise LAN to allow for communication with each controller on the network as specified in Paragraph D.
    3. Network operator interface and value passing shall be transparent to internetwork architecture.
       1. An operator interface connected to the BAS shall allow the operator to interface with each networked controller as if directly connected. BAS information such as data, status, reports, system software, and custom programs shall be viewable and editable.
       2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be available on the network. Program and test all cross-controller links required to execute specified BAS operation. An authorized operator shall be able to manage, maintain, and access the BAS network of controllers.
    4. System shall be expandable to at least twice the required data points with additional controllers, associated devices, and wiring. Expansion shall not require operator interface hardware additions or software revisions.
    5. Workstation, building control panels, and controllers with real-time clocks shall use the open- protocol time synchronization service. The system shall automatically synchronize system clocks daily from an operator-designated device via the internetwork. The system shall automatically adjust for daylight savings and standard time as applicable.

## OPERATOR INTERFACE

* + 1. PC-based workstations shall reside on a high-speed network with building controllers as shown on the system drawings. Each workstation or standard browser connected to the server shall be able to access all BAS information.
    2. Multiple users shall be able to access BAS information from different locations simultaneously.

## PHYSICAL SYSTEM CONNECTION

* + 1. Workstation and controllers shall communicate using an open protocol. Workstation and control network backbone shall communicate using ISO 8802-3 (Ethernet) data link/physical layer protocol and {open protocol} addressing as specified in open-protocol body guidelines and requirements.

## HARDWARE

* + 1. Each operator workstation or webserver shall consist of the following:
       1. Computer. Hardware shall meet or exceed BAS manufacturer's recommended specifications and shall meet response times specified elsewhere in this document. The following hardware requirements also apply:
          1. The hard disk shall have sufficient memory to store all required operator workstation software.
          2. A BAS database at least twice the size of the delivered system database.
          3. One year of trend data based on the points specified to be trended at their specified trend intervals.
          4. Provide additional hardware (communication ports, video drivers, network interface cards, cabling, etc.) to facilitate all control functions and software requirements specified for the DDC system.
          5. Minimum hardware configuration shall include the following: {This section needs to be updated continuously. The BAS designer needs to insert the appropriate language here}.

## SYSTEM SOFTWARE

* + 1. Operating System. Furnish a concurrent multitasking operating system. The operating system also shall support the use of other common software applications. Examples include Microsoft Excel, Microsoft Access, or other SQL database software. Acceptable operating systems are Windows, the latest Windows Server release, Linux, and UNIX.

## SYSTEM GRAPHICS

* + 1. The operator workstation software shall be graphically oriented. The system shall allow display of up to ten graphic screens at once for comparison and monitoring of system status. Provide a method for the operator to easily move between graphic displays and change the size and location of graphic displays on the screen. The system graphics shall be able to be modified while online. An operator with the proper password level shall be able to add, delete, or change dynamic objects on a graphic. Dynamic objects shall include analog and binary values, dynamic text, static text, and animation files. Graphics shall have the ability to show animation by shifting image files based on the status of the object.
    2. Custom Graphics. Custom graphic files shall be created with the use of a graphics generation package furnished with the system. The graphics generation package shall be a graphically based system that uses the mouse to create and modify graphics that are saved in industry standard formats such as PCX, TIFF, and GEM. The graphics generation package also shall provide the capability of capturing or converting graphics from other programs, such as Designer or AutoCAD.
    3. Graphics Library. Furnish a complete library of standard HVAC equipment graphics, such as chillers, boilers, air handlers, terminals, fan-coils, and unit ventilators. This library also shall include standard symbols for other equipment, including fans, pumps, coils, valves, piping, dampers, and ductwork. The library shall be furnished in a file format compatible with the graphics generation package program.

## SYSTEM APPLICATIONS

* + 1. Each workstation shall provide operator interface and offline storage of system information. Provide the following applications at each workstation:
       1. Automatic System Database Save and Restore. Each workstation shall store on the hard disk a copy of the current database of each building controller. This database shall be updated whenever a change is made in any system panel. The storage of these data shall be automatic and not require operator intervention. In the event of a database loss in a building management panel, the first workstation to detect the loss shall automatically restore the database for that panel. This capability may be disabled by the operator.
       2. Manual Database Save and Restore. A system operator with the proper password clearance shall be able to save the database from any system panel. The operator also shall be able to clear a panel database and manually initiate a download of a specified database to any panel in the system.
    2. System Configuration
       1. The workstation software shall provide a method of configuring the system. This shall allow for future system changes or additions by users under proper password protection.
    3. Online Help
       1. Provide a context-sensitive, online help system to assist the operator in operating and editing the system. Online help shall be available for all applications and shall provide the relevant data for that particular screen. Additional help information shall be available through the use of hypertext.
    4. Security
       1. Each operator shall be required to log on to the system with a username and password in order to view, edit, add, or delete data. System security shall be selectable for each operator. The system supervisor shall have the ability to set passwords and security levels for all other operators. Each operator password shall be able to restrict the functions accessible to viewing and/or changing each system application, editor, and object. Each operator shall automatically be logged off of the system if no keyboard or mouse activity is detected. This

auto logoff time period shall be user adjustable. All system security data shall be stored in an encrypted format.

## SYSTEM DIAGNOSTICS

* + 1. The system shall automatically monitor the operation of all workstations, printers, network connections, building management panels, and controllers. The failure of any device shall be annunciated to the operator.

## ALARM PROCESSING

* + 1. Any object in the system shall be configurable to alarm in and out of normal state. The operator shall be able to configure the alarm limits, alarm limit differentials, states, and reactions for each object in the system.
    2. Alarm Messages. Alarm messages shall use the English language descriptor for the object in alarm in such a way that the operator will be able to recognize the source, location, and nature of the alarm without relying on acronyms or other mnemonics.
    3. Alarm Reactions. The operator shall be able to determine (by object) what, if any, actions are to be taken during an alarm. Actions shall include logging, printing, starting programs, displaying messages, dialing out to remote stations, paging, providing audible annunciation, or displaying specific system graphics. Each of these actions shall be configurable by workstation and time of day.

## TREND, ALARMS AND EVENT LOGS

* + 1. Trend Logs. The operator shall be able to define a custom trend log for any data object in the system. This definition shall include interval, start time, and stop time. Trend data shall be sampled and stored on the building controller panel, be archived on the hard disk, and be retrievable for use in spreadsheets and standard database programs. Trend data shall be exportable in a standard electronic format [(.xls, .csv, .xml)] for analysis external to the BAS.
    2. Alarm and Event Log. The operator shall be able to view all system alarms and change of states from any location in the system. Events shall be listed chronologically. An operator with the proper security level may acknowledge and clear alarms. All that have not been cleared by the operator shall be archived to the hard disk on the workstation.
    3. Group Trend Time Series Plots
       1. Provide user-selectable Y points.
       2. Provide user-editable titles, point names, and Y axis titles.
       3. Individual trended points shall be able to be grouped in groups of up to four points per plot with up to four plots per page.
    4. X-Y Trend Plots
       1. User-selectable X and Y trend inputs
       2. User-editable titles, point names, and X and Y axis titles
       3. User-selectable time period options:
          1. One-day 24-hour period
          2. One-week seven-day period
          3. One-month period, with appropriate days for the month selected
          4. One-year period

The user shall be able to select the beginning and ending period for each X-Y chart within the time domain of the database being used.

* + - * 1. User-selectable display of up to six plots per screen in two columns
    1. Object and Property Status and Control
       1. Provide a method for the operator to view, and edit (if applicable), the status of any object and property in the system. The status shall be available by menu, on graphics, or through custom programs.
    2. Reports and Logs
       1. Provide a reporting package that allows the operator to select, modify, or create reports. Each report shall be definable as to data content, format, interval, and date. Report data shall be archivable on the hard disk for historical reporting. Provide the ability for the operator to obtain real-time logs of all objects by type or status (e.g., alarm, lockout, normal). Reports and logs shall be stored on the PC hard disk in a format that is readily accessible by other standard software applications, including spreadsheets and word processing. Reports and logs shall be readily printed to the system printer and shall be set to be printed either on operator command or at a specific time each day.
    3. Standard Reports
       1. The following standard BAS reports shall be provided for this project. Provide ability for the owner to readily customize these reports for this project. (Note to designer: This specification lists some commonly required standard reports.)
          1. All Objects/Points/Variables. All system (or subsystem) objects, points, variables, configuration properties, and their current values
          2. Alarm Summary. All current alarms (except those in alarm lockout)
          3. Disabled Objects/Points. All objects/points that are disabled
          4. Alarm Lockout Objects/Points. All objects/points in alarm lockout (whether manual or automatic)
          5. Alarm Lockout Objects/Points in Alarm. All objects/points in alarm lockout that are currently in alarm
          6. Logs

Alarm history

System messages

System events

Trends

* + 1. Custom Reports
       1. Provide the capability for the operator to easily define any system data into a daily, weekly, monthly, or annual report. These reports shall be time and date stamped and shall contain a report title and the name of the facility.
    2. Tenant Override Report
       1. Provide a monthly report showing the daily total time in hours that each tenant has requested after-hours HVAC and lighting services. Provide an annual summary report that shows the override usage on a monthly basis.
    3. Electrical, Gas, and Weather Reports
       1. Electrical Meter Report. Provide a monthly report showing the daily electrical consumption and peak electrical demand with time and date stamp for each building meter.
       2. Provide an annual (12-month) summary report showing the monthly electrical consumption and peak demand with time and date stamp for each meter.
       3. Gas Meter Report. Provide a monthly report showing the daily natural gas consumption for each meter. Provide an annual (12-month) report that shows the monthly consumption for each meter.
       4. Weather Data Report. Provide a monthly report showing the daily minimum, maximum, and average outdoor air temperature, as well as the number of heating and cooling degree- days for each day. Provide an annual (12-month) report showing the minimum, maximum, and average outdoor air temperature for the month, as well as the number of heating and cooling degree-days for the month. If there is a weather station within 25 miles of the facility, provide real-time weather information via SOAP/XML. Otherwise, use weather values from the BAS.
    4. Electrical, Gas, and Weather Graphic Display
       1. Provide a graphic display for each electrical meter and gas meter and weather data point(s) with a data table and a current 24-hour trend plot. Include data values for the following time periods: today, previous day, week to date, previous week, month to date, previous month, year to date, previous year.
    5. ANSI/ASHRAE Standard 147 Report:
       1. Provide a daily report that shows the operating condition of each chiller as recommended by ANSI/ASHRAE Standard 147. At a minimum, this report shall include:
          1. Chilled-water (or other secondary coolant) inlet and outlet temperature
          2. Chilled-water (or other secondary coolant) flow
          3. Chilled-water (or other secondary coolant) inlet and outlet pressures
          4. Evaporator refrigerant pressure and temperature
          5. Condenser refrigerant pressure and liquid temperature
          6. Condenser-water inlet and outlet temperatures
          7. Condenser-water flow
          8. Refrigerant levels
          9. Oil pressure and temperature
          10. Oil level
          11. Compressor refrigerant discharge temperature
          12. Compressor refrigerant suction temperature
          13. Addition of refrigerant
          14. Addition of oil
          15. Vibration levels, or observation that vibration is not excessive
          16. Motor amperes per phase
          17. Motor volts per phase
          18. PPM refrigerant monitor level
          19. Purge exhaust time or discharge count
          20. Ambient temperature (dry-bulb and wet-bulb)
          21. Date and time logged

## WORKSTATION APPLICATION EDITORS

* + 1. Each PC workstation shall support editing of all system applications. Provide editors for each application at the PC workstation. The applications shall be downloaded and executed at one or more of the controller panels.
    2. Controller
       1. Provide a full-screen editor for each type of application that shall allow the operator to view and change the configuration, name, control parameters, and set points for all controllers.
    3. Scheduling
       1. An editor for the scheduling application shall be provided at each workstation. Provide a method of selecting the desired schedule and month. This shall consist of a monthly calendar for each schedule. Exception schedules and holidays shall be shown clearly on the calendar. Provide a method for allowing several related objects to follow a schedule. The start and stop times for each object shall be adjustable from this master schedule. Schedules shall be easy to copy to other objects and/or dates.
    4. Custom Application Programming
       1. Provide the tools to create, modify, and debug custom application programming. The operator shall be able to create, edit, and download custom programs at the same time that all other system applications are operating. The BAS shall be fully operable while custom routines are edited, compiled, and downloaded. The programming language shall have the following features:
          1. The language shall be line-by-line text based, based on the syntax of BASIC, FORTRAN, C, or PASCAL, and allow for free-form programming (i.e., not column-oriented or “fill in the blanks”). Alternatively, the programming language can be graphically based using function blocks as long as blocks are available that directly provide the functions listed below and that custom or compound function blocks can be created.
          2. A full-screen character editor/programming environment shall be provided. The editor shall be cursor/mouse-driven and allow the user to insert, add, modify, and delete custom programming code. It also shall incorporate word processing features such as cut/ paste and find/replace. The debugger also shall provide error messages for syntax and execution errors.
          3. The programming language shall support conditional statements (IF/THEN/ELSE/ ELSE-IF) using compound Boolean (AND, OR, and NOT) and/or relations (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.
          4. The programming language shall support floating-point arithmetic using the following operators: +, -, ?, ×, and square root. The following mathematical functions also shall be provided: absolute value and minimum/maximum value from a list of values.
          5. The programming language shall have predefined variables that represent time of day, day of the week, month of the year, and the date. Other predefined variables shall provide elapsed time in seconds, minutes, hours, and days. These elapsed time variables shall be able to be reset by the language so that interval-timing functions can be stopped and started within a program. Values from all of the above variables shall be readable by the language so that they can be used in a program for such purposes as IF/THEN comparisons, calculations, etc.
          6. The language shall be able to read the values of the variables and use them in programming statement logic, comparisons, and calculations.
          7. The programming language shall have predefined variables representing the status and results of the system software and shall be able to enable, disable, and change the set points of the system software.
          8. The programming language shall allow independently executing program modules to be developed. Each module shall be able to independently enable and disable other modules.
          9. The editor/programming environment shall have a debugging/simulation capability that allows the user to step through the program and observe any intermediate values and/ or results.
    5. Portable Operator’s Terminal. Furnish a portable operator’s terminal that shall be capable of accessing all BAS data. This device may be connected to any point on the system network or may be connected directly to any controller for programming, setup, and troubleshooting. This device may be connected to any point on the system network or it may be connected directly to controllers using open protocol. The portable operator’s terminal shall be a notebook-style PC including all software and hardware required. The PC shall contain at minimum: {BAS designer needs to update this requirement for the project.}

## CONTROLLER SOFTWARE

* + 1. Furnish the following applications software for building and energy management. All software applications shall reside and operate in the system controllers. Editing of applications shall occur at the operator workstation.
    2. System Security
       1. User access shall be secured using individual security passwords and usernames.
       2. Passwords shall restrict the user to the objects, applications, and system functions as assigned by the system manager.
       3. User log-on/log-off attempts shall be recorded.
       4. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user definable.
       5. All administrator passwords for the system, including operation, system management, database management, and device programming must be identified and submitted to the owner.
    3. System Coordination. Provide a standard application for the proper coordination of equipment. This application shall provide the operator with a method of grouping together equipment based on function and location. This group may then be used for scheduling and other applications.
    4. Scheduling. Provide the capability to schedule each object or group of objects in the BAS. Each schedule shall consist of the following:
       1. Weekly Schedule. Provide separate schedules for each day of the week. Each of these schedules should include the capability for start, stop, optimal start, optimal stop, and night economizer. Each schedule may consist of up to ten events. When a group of objects are scheduled together, provide the capability to adjust the start and stop times for each member.
       2. Exception Schedules. Provide the ability for the operator to designate any day of the year as an exception schedule. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by the standard schedule for that day of the week.
       3. Holiday Schedules. Provide the capability for the operator to define up to 99 special or holiday schedules. These schedules may be placed on the scheduling calendar and will be repeated each year. The operator shall be able to define the length of each holiday period.
       4. Before project close-out, the contractor shall create schedules for each piece of equipment (not just provide the capability to do so).
    5. Binary Alarms. Each binary object shall be set to alarm based on the operator-specified state. Provide the capability to automatically and manually disable alarming.
    6. Analog Alarms. Each analog object shall have both high and low alarm limits. Alarming must be able to be automatically and manually disabled.
    7. Alarm Reporting. The operator shall be able to determine the action to be taken in the event of an alarm. Alarms shall be routed to the appropriate workstations based on time and other conditions. An alarm shall be able to start programs, print, be logged in the event log, generate custom messages, and display graphics.
    8. Remote Communication. The system shall have the ability to transmit the alarm/event using the {open protocol} control network.
    9. Demand Limiting
       1. The demand-limiting program shall monitor building power consumption from signals generated by a pulse generator (provided by others) mounted at the building power meter or from a watt transducer or current transformer attached to the building feeder lines.
       2. The demand-limiting program shall predict the probable power demand such that action can be taken to prevent exceeding the demand limit. When demand prediction exceeds demand limit, action will be taken to reduce loads in a predetermined manner. When demand prediction indicates the demand limit will not be exceeded, action will be taken to restore loads in a predetermined manner
       3. Demand reduction shall be accomplished by the following means:
          1. Reset air-handling unit supply temperature set point up by 1°C (2°F).
          2. Reset space temperature set points up by 1°C (2°F).
          3. De-energize equipment based upon priority.
       4. Demand-limiting parameters, frequency of calculations, time intervals, and other relevant variables shall be based on the means by which the local power company computes demand charges.
       5. Provide demand-limiting prediction and control for any individual meter monitored by the system or for the total of any combination of meters.
       6. Provide the means for an operator to make the following changes online:
          1. Addition and deletion of loads controlled
          2. Changes in demand intervals
          3. Changes in demand limit for meter(s)
          4. Maximum shutoff time for equipment
          5. Minimum shutoff time for equipment
          6. Select rotational or sequential shedding and restoring
          7. Shed/restore priority
    10. Provide the following information and reports to be available on an hourly, daily, and monthly basis:
        1. Total electric consumption
        2. Peak demand
        3. Date and time of peak demand
        4. Daily peak demand
    11. Maintenance Management. The system shall monitor equipment status and generate maintenance messages based on user-designated runtime, starts, and/or calendar date limits.
    12. Sequencing. Provide application software based on the sequences of operation specified to properly sequence chillers, boilers, and pumps.
    13. PID Control. A PID algorithm with direct or reverse action and anti-windup shall be supplied. The algorithm shall calculate a time-varying analog value that is used to position an output or stage a series of outputs. The controlled variable, set point, and PID gains shall be user selectable.
    14. Staggered Start. This application 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.
    15. Energy Calculations
        1. Provide software to allow instantaneous power (e.g., kW) or flow rates (e.g., L/s [gpm]) to be accumulated and converted to energy use data.
        2. Provide an algorithm that calculates a sliding-window average (e.g., rolling average). The algorithm shall be flexible to allow window intervals to be user specified (e.g., 15 min, 30 min, 60 min).
        3. Provide an algorithm that calculates a fixed-window average. A digital input signal will define the start of the window period (e.g., signal from utility meter) to synchronize the fixed-window average with that used by the energy service provider.
        4. Provide for the collection and recording of energy data from devices such as pump VFDs and chillers.
    16. Anti-Short-Cycling. All binary output objects shall be protected from short cycling. This feature shall allow minimum on-time and off-time to be selected.
    17. On/Off Control with Differential. Provide an algorithm that allows a binary output to be cycled based on a controlled variable and set point. The algorithm shall be direct-acting or reverse- acting and incorporate an adjustable differential.
    18. Runtime Totalization. Provide software to totalize runtimes for all binary input objects. A high runtime alarm shall be assigned, if required, by the operator.

## BUILDING CONTROLLERS

* + 1. General. Provide an adequate number of building controllers to achieve the performance specified in Article 1.9. Each of these controllers shall meet the following requirements.
       1. The BAS shall be composed of one or more independent, stand-alone, microprocessor- based building controllers to manage the global strategies described in Article 2.8, “System Software.”
       2. The building controller shall have sufficient memory to support its operating system, database, and programming requirements.
       3. Memory and point mapping capabilities for points from systems provided by other.
       4. Data shall be shared between networked building controllers.
       5. The operating system of the building controller shall manage the input and output communication signals to allow distributed controllers to share real and virtual object/variable information and allow for central monitoring and alarms.
       6. Controllers that perform scheduling shall have a real-time clock.
       7. The building controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall
          1. Assume a predetermined failure mode
          2. Generate an alarm notification
       8. The building controller shall communicate with networked BAS devices on the network using the protocol-specific communication requirements. Controller-to-controller communication shall be peer-to-peer and not require a master or host server for communication.
       9. The building controller shall be certified, listed by or submitted for testing to a testing laboratory approved by open-protocol body.
    2. Communication
       1. Each building controller shall reside on the open-protocol network.
       2. The controller shall provide a communication port connection or network interface for a portable operator’s terminal.
       3. Network routers/repeaters/bridges shall be used to extend communications, change media type, or extend the network in order to ensure proper communication for the entire BAS.
       4. BAS networking responsibilities for devices provided by others: both IP and non-IP.
    3. Environment. Controller hardware shall be suitable for the anticipated ambient conditions.
       1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within water- proof enclosures and shall be rated for operation at –40°C to 65°C (–40°F to 150°F).
       2. Controllers used in conditioned space shall be mounted in dust-proof enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
    4. Keypad. A local keypad and display shall be provided for each controller. The keypad shall be provided for interrogating and editing data. An optional system security password shall be available to prevent unauthorized use of the keypad and display. If the manufacturer does not provide this keypad and display, provide a portable operator terminal (optional at BAS designer’s discretion).
    5. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
    6. Memory. The building controller shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.
    7. Immunity to Power and Noise. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).

## Custom Application Controllers

* + 1. General. Provide an adequate number of custom application controllers to achieve the performance specified in Article 1.9. Each of these panels shall meet the following requirements.
       1. The custom application controller shall have sufficient memory to support its operating system, database, and programming requirements.
       2. Data shall be shared between networked custom application controllers.
       3. The operating system of the controller shall manage the input and output communication signals to allow distributed controllers to share real and virtual object information and allow central monitoring and alarms.
       4. Controllers that perform scheduling shall have a real-time clock.
       5. The custom application controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall
          1. assume a predetermined failure mode and
          2. generate an alarm notification
       6. The custom application controller shall communicate with other open-protocol devices on the network using the protocol-specific services.
       7. All network controllers shall be tested and certified or listed by an official open-protocol testing laboratory as being compliant with the standardized open-protocol device capabilities.
       8. Each controller shall have 15% spare input/output capacity for future expansion.
    2. Communication
       1. Each custom application controller shall reside on a control network using the device-level protocol.
       2. The controller shall provide a service communication port or network interface using an open protocol for connection to a portable operator’s terminal.
    3. Environment. Controller hardware shall be suitable for the anticipated ambient conditions.
       1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within water- proof enclosures and shall be rated for operation at –40°C to 65°C (–40°F to 150°F).
       2. Controllers used in conditioned space shall be mounted in dustproof enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
    4. Keypad. A local keypad and display shall be provided. The keypad shall be provided for interrogating and editing data. An optional system security password shall be available to prevent unauthorized use of the keypad and display.
    5. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
    6. Memory. The building controller shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.
    7. Immunity to Power and Noise. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).

## APPLICATION-SPECIFIC CONTROLLERS

* + 1. General. Application-specific controllers (ASCs) are microprocessor-based BAS controllers that through hardware or firmware design are dedicated to control a specific piece of equipment. They are not fully user-programmable but are customized for operation within the confines of the equipment they are designed to serve. ASCs shall communicate with other BAS open-protocol devices on the network using the open-protocol-specific read (execute) property service.
       1. Each ASC shall be capable of stand-alone operation and shall continue to provide control functions without being connected to the network.
       2. Each ASC will contain sufficient I/O capacity to control the target system.
       3. Each ASC shall be certified or listed for compliance to the open-protocol body standards.
       4. Each controller shall have 15% spare input/output capacity for future expansion.
    2. Communication
       1. Each custom application controller shall reside on a control network using the device-level protocol.
       2. The controller shall provide a service communication port or network interface using an open protocol for connection to a portable operator’s terminal.
    3. Environment. Controller hardware shall be suitable for the anticipated ambient conditions.
       1. Controllers used outdoors and/or in wet ambient conditions shall be mounted within water- proof enclosures and shall be rated for operation at –40°C to 65°C (–40°F to 150°F).
       2. Controllers used in conditioned space shall be mounted in dustproof enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
    4. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
    5. Memory. The building controller shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.
    6. Immunity to Power and Noise. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft)
    7. Transformer. Power supply for the ASC must be rated at a minimum of 125% of ASC power consumption and shall be of the fused or current limiting type.

## INPUT/OUTPUT INTERFACE

* + 1. All points shall be visible through BAS, including but not limited to inputs, outputs, and virtual and internal points.
    2. Hardwired inputs and outputs may tie into the BAS through building, custom application, or application-specific controllers.
    3. All input points and output points shall be protected such that shorting of the point to itself, to another point, or to ground will cause no damage to the controller. All input and output points

shall be protected from up to 24 V of any duration, such that contact with this voltage will cause no damage to the controller.

* + 1. Binary inputs shall allow the monitoring of on/off signals from remote devices. The binary inputs shall provide a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against the effects of contact bounce and noise. Binary inputs shall sense dry-contact closure without external power (other than that provided by the controller) being applied.
    2. Pulse Accumulation Input Objects. This type of object shall conform to all the requirements of binary input objects and also accept up to ten pulses per second for pulse accumulation.
    3. Analog inputs shall allow the monitoring of low-voltage (0 to 10 VDC), current (4 to 20 mA), or resistance signals (thermistor, RTD). Analog inputs shall be compatible with—and field configurable to—commonly available sensing devices.
    4. Binary outputs shall provide for on/off operation or a pulsed low-voltage signal for pulse width modulation control. Binary outputs on building and custom application controllers shall have three-position (on/off/auto) override switches and status lights. Outputs shall be selectable for either normally open or normally closed operation.
    5. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0 to 10 VDC or a 4 to 20 mA signal as required to provide proper control of the output device. Analog outputs on building or custom application controllers shall have status lights and a two-position (AUTO/MANUAL) switch and manually adjustable potentiometer for manual override. Analog outputs shall not exhibit a drift of greater than 0.4% of range per year.
    6. Tristate Outputs. Provide tristate outputs (two coordinated binary outputs) for control of three- point floating-type electronic actuators without feedback. Use of three-point floating devices shall be limited to zone control and terminal-unit control applications (VAV terminal units, duct- mounted heating coils, zone dampers, radiation, etc.). Control algorithms shall run the zone actuator to one end of its stroke once every 24 hours for verification of operator tracking.
    7. Universal I/O
       1. I/O points shall be the universal type—i.e., controller input or output may be designated (in software) as either a binary or analog type point with appropriate properties. ASCs are exempt from this requirement.
       2. System Capacity. The system size shall be expandable to at least twice the number of input/ output objects/points required for this project. Additional controllers (along with associated devices and wiring) shall be all that is necessary to achieve this capacity requirement. The operator interfaces installed for this project shall not require any hardware additions or software revisions in order to expand the system.

## POWER SUPPLIES AND LINE FILTERING

* + 1. DC power supply output shall match output current and voltage requirements. Unit shall be full- wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100 microsecond response time for 50% load changes. Unit shall have built-in overvoltage and overcurrent protection and shall be able to withstand a 150% current overload for at least three seconds without trip-out or failure.
       1. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B.
       2. Line voltage units shall be UL recognized and CSA approved.
    2. Provide transient voltage and surge suppression for all workstations and controllers either internally or as an external component. Surge protection shall have the following at a minimum:
       1. Dielectric strength of 1000 V minimum
       2. Response time of 10 nanoseconds or less
       3. Transverse-mode noise attenuation of 65 dB or greater
       4. Common-mode noise attenuation of 150 dB or better at 40 to 100 Hz

## AUXILIARY CONTROL DEVICES

* + 1. Motorized control dampers, unless otherwise specified elsewhere, shall be as follows:
       1. Control dampers shall be the parallel- or opposed-blade type as below or as scheduled on drawings:
          1. Outdoor and/or return-air mixing dampers and face and bypass dampers shall be parallel blade, arranged to direct airstreams toward each other.
          2. Other modulating dampers shall be the opposed-blade type.
          3. Two-position shutoff dampers may be parallel- or opposed-blade type with blade and side seals.
       2. Damper frames shall be 13 gage galvanized steel channel or 3.2 mm (1/8 in.) extruded aluminum with reinforced corner bracing.
       3. Damper blades shall not exceed 20 cm (8 in.) in width or 125 cm (48 in.) in length. Blades are to be suitable for medium-velocity performance (10 m/s [2000 fpm]). Blades shall be not less than 16 gage (1.29 mm).
       4. Damper shaft bearings shall be as recommended by manufacturer for application, oil impregnated sintered bronze or better.
       5. All blade edges and top and bottom of the frame shall be provided with replaceable butyl rubber or neoprene seals. Side seals shall be spring-loaded stainless steel. The blade seals shall provide for a maximum leakage rate of 50 L/s·m2 (10 cfm per ft2) at 1000 Pa (4 in. of water) differential pressure. Provide air foil blades suitable for a wide-open face velocity of 7.5 m/s (1500 fpm).
       6. Individual damper sections shall not be larger than 125×150 cm (48×60 in.). Provide a minimum of one damper actuator per section.
       7. Modulating dampers shall provide a linear flow characteristic where possible.
       8. Dampers shall have exposed linkages.
    2. Electric Damper/Valve Actuators
       1. The actuator shall have mechanical or electric stall protection to prevent damage to the actuator throughout the rotation of the actuator.
       2. Where shown, for power-failure/safety applications, an internal mechanical spring-return mechanism shall be built into the actuator housing. Alternatively, an uninterruptible power supply (UPS) may be provided.
       3. Proportional actuators shall accept a 0 to 10 VDC or 0 to 20 mA control signal and provide a 2 to 10 VDC or 4 to 20 mA operating range.
       4. All 24 VAC/VDC actuators shall operate on Class 2 wiring.
       5. All non-spring-return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered. Spring-return actuators with more than 7 N·m (60 in.·lb) torque capacity shall have a manual crank for this purpose.
       6. Instruments, actuators and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments and actuators not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall 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:

Chiller and boiler rooms: Type 4

Air-moving equipment rooms: Type 2

* + - * 1. Localized areas exposed to wash down: Type 4X
        2. Within duct systems and air-moving equipment not exposed to possible condensation:

Type 3

* + - * 1. Within duct systems and air-moving equipment exposed to possible condensation: Type 4
    1. Pneumatic Damper/Valve Actuators and Positioners
       1. Pneumatic actuators shall be piston-rolling diaphragm type or diaphragm type with easily replaceable, beaded, molded neoprene diaphragm.
       2. Actuator housings may be molded or die-cast zinc or aluminum. Exception: Actuator housings for terminal-unit zone-control dampers or valves may be of high-impact plastic construction with an ambient temperature rating of 10°C to 60°C (50°F to 140°F) minimum. However, any plastic devices located in return air (ceiling) plenums shall be isolated from plenums with an auxiliary metal enclosure having a quick-opening access panel.
       3. Actuator size and spring ranges selected shall be suitable for intended application.
       4. Rate pneumatic actuators for a minimum 140 kPa (20 psig).
       5. Damper actuators shall be selected in accordance with manufacturer’s recommendations to provide sufficient close-off force to effectively seal damper and to provide smooth modulating control under design flow and pressure conditions. Furnish a separate actuator for each damper section.
       6. Valve actuators shall provide tight close-off at design system pressure and shall provide smooth modulation at design flow and pressure conditions.
       7. On sequencing applications, valve and damper actuators shall be sized for a maximum of 14 kPa (2 psi) shift in nominal spring range. Spring ranges shall be selected to prevent overlap, or positive positioners shall be provided.
       8. Positive positioners to have the following performance characteristics:
          1. Linearity: ±10% of output signal span
          2. Hysteresis: 3% of the span
          3. Response: 1/4 psig input change
          4. Maximum pilot signal pressure: 140 kPa (20 psig)
          5. Maximum control air supply pressure: 420 kPa (60 psig)
       9. Positive positioners shall be provided on actuators for inlet vane control and on any other actuators where required to provide smooth modulation or proper sequencing.
       10. Positive positioners shall be high-capacity force balance relay type with suitable mounting provisions and position feedback linkage tailored for particular actuator.
       11. Positive positioners shall use full-control air pressure at any point in stem travel to initiate stem movement or to maintain stem position. Positioners shall operate on a 20 to 100 kPa (3 to 15 psig) input signal unless otherwise required to satisfy the control sequences of operation.
    2. Control Valves
       1. Control valves shall be two-way or three-way type for two-position or modulating service as shown.
       2. Close-off (differential) Pressure Rating. Valve actuator and trim shall be furnished to provide the following minimum close-off pressure ratings:
          1. Water Valves

Two-way: 150% of total system (pump) head

Three-way: 300% of pressure differential between Ports A and B at design flow or 100% of total system (pump) head

* + - * 1. Steam Valves: 150% of operating (inlet) pressure
      1. Water Valves
         1. Body and trim style and materials shall be in accordance with manufacturer’s recommendations for design conditions and service shown, with equal percentage ports for modulating service.
         2. Sizing Criteria

Two-position service: Line size

Two-way modulating service: Pressure drop shall be equal to twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 34.5 kPa(5 psi), whichever is greater.

Three-way modulating service: Pressure drop equal to twice the pressure drop through the coil exchanger (load), 34.5 kPa (5 psi) maximum.

Valves DN 15 (1/2 in.) through DN 50 (2 in.) shall be bronze body or cast brass ANSI Class 250 (PN18), spring-loaded, PTFE packing, quick opening for two-position service. Two-way valves to have replaceable composition disc or

stainless-steel ball.

Valves DN 65 (2 1/2 in.) and larger shall be cast iron ANSI Class 125 (PN 6) with guided plug and PTFE packing.

* + - * 1. Water valves shall fail normally open or closed, as scheduled on plans, or as follows:

Water zone valves: Normally open preferred

Heating coils in air handlers: Normally open

Chilled-water control valves: Normally closed

Other applications: As scheduled or as required by sequences of operation

* + - 1. Steam Valves
         1. Body and trim materials shall be in accordance with manufacturer’s recommendations for design conditions and service with linear ports for modulating service.
         2. Sizing Criteria

Two-position service: Pressure drop 10% to 20% of inlet psig

Modulating service: 100 kPa (15 psig) or less; pressure drop 80% of inlet psig

Modulating service: 101 to 350 kPa (16 to 50 psig); pressure drop 50% of inlet psig

Modulating service: Over 350 kPa (50 psig); pressure drop as scheduled on plans

* + 1. Binary Temperature Devices
       1. Low-voltage space thermostat shall be 24 V, bimetal-operated, mercury-switch type, with either adjustable or fixed anticipation heater, concealed set-point adjustment, 13°C to 30°C (55°F to 85°F) set-point range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
       2. Line-voltage space thermostat shall be bimetal-actuated, open contact type, or bellows- actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listed for electrical rating, concealed set-point adjustment, 13°C to 30°C (55°F to 85°F) set-point range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
       3. Low-limit airstream thermostats shall be UL listed, vapor pressure type, with an element of 6 m (20 ft) minimum length. Element shall respond to the lowest temperature sensed by any 30 cm (1 ft) section. The low-limit thermostat shall be manual reset only.
    2. Temperature Sensors
       1. Temperature sensors shall be RTD or thermistor.
       2. Duct sensors shall be single-point or averaging as shown. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m2 (10 ft2) of duct cross section.
       3. Immersion sensors shall be provided with a separable stainless-steel well. Pressure rating of well is to be consistent with the system pressure in which it is to be installed. The well must withstand the flow velocities in the pipe.
       4. Space sensors shall be equipped with set-point adjustment, override switch, display, and/or communication port.
       5. Provide matched temperature sensors for differential temperature measurement.
    3. Humidity Sensors
       1. Duct and room sensors shall have a sensing range of 20% rh to 80% rh.
       2. Duct sensors shall be provided with a sampling chamber.
       3. Outdoor air humidity sensors shall have a sensing range of 20% rh to 95% rh. They shall be suitable for ambient conditions of 40°C to 75°C (40°F to 170°F).
       4. Humidity sensor drift shall not exceed 1% of full scale per year.
    4. Flow Switches
       1. Flow-proving switches shall be either paddle or differential-pressure type.
       2. Paddle-type switches (water service only) shall be UL listed, SPDT snap-acting with pilot duty rating (125 VA minimum) and shall have adjustable sensitivity with NEMA 1, IP 20 enclosure unless otherwise specified.
       3. Differential-pressure type switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum), NEMA 1, IP 20 enclosure, with scale range and differential suitable for intended application or as specified.
    5. Relays
       1. Control relays shall be UL listed plug-in type with dust cover and LED energized indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
       2. Time delay relays shall be UL listed solid-state plug-in type with adjustable time delay. Delay shall be adjustable ±200% (minimum) from set point shown on plans. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1, IP 20 enclosure when not installed in local control panel.
    6. Override Timers
       1. Override timers shall be spring-wound line voltage, UL Listed, with contact rating and configuration as required by application. Provide 0-to-6-hour calibrated dial unless otherwise specified. Timer shall be suitable for flush mounting on control-panel face and located on local control panels or where shown.
    7. Current Transmitters
       1. AC current transmitters shall be the self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4 to 20 mA two-wire output. Unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A full scale, with internal zero and span adjustment and ±1% full-scale accuracy at 500 ohm maximum burden.
       2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.
       3. Unit shall be split-core type for clamp-on installation on existing wiring.
    8. Current Transformers
       1. AC current transformers shall be UL/CSA recognized and completely encased (except for terminals) in approved plastic material.
       2. Transformers shall be available in various current ratios and shall be selected for ±1% accuracy at 5 A full-scale output.
    9. Voltage Transmitters
       1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4 to 20 mA output with zero and span adjustment.
       2. Ranges shall include 100 to 130 VAC, 200 to 250 VAC, 250 to 330 VAC, and 400 to 600 VAC full-scale, adjustable, with ±1% full-scale accuracy with 500 ohm maximum burden.
       3. Transmitters shall be UL/CSA recognized at 600 VAC rating and meet or exceed ANSI/ISA S50.1 requirements.
    10. Voltage Transformers
        1. AC voltage transformers shall be UL/CSA recognized, 600 VAC rated, complete with built- in fuse protection.
        2. Transformers shall be suitable for ambient temperatures of 4°C to 55°C (40°F to 130°F) and shall provide ±0.5% accuracy at 24 VAC and a 5 VA load.
        3. Transformers shall be fixed-core or split-core type for installation on new or existing wiring, respectively.
        4. Windings (except for terminals) shall be completely enclosed with metal or plastic material.
    11. Power Monitors
        1. Selectable rate pulse output for kilowatt-hour reading, 4 to 20 mA output for kilowatt reading, N.O. alarm contact, and ability to operate with 5.0 A current inputs or 0 to 0.33 V inputs
        2. One-percent (1.0%) full-scale true RMS power accuracy, +0.5 Hz, voltage input range 120 to 600 V, and auto range select
        3. Under voltage/phase monitor circuitry
        4. NEMA 1, IP 20 enclosure
        5. Current transformers having a 0.5% FS accuracy, 600 VAC isolation voltage with 0 to

0.33 V output. If 0 to 5 A current transformers are provided, a three-phase disconnect/ shorting switch assembly is required.

* + - 1. Optional serial communication meters may be offered as an alternate bid.
    1. Hydronic Flowmeters
       1. Insertion-Type Turbine Meter
          1. Dual counter-rotating axial turbine elements, each with its own rotational sensing system, and an averaging circuit to reduce measurement errors due to swirl and flow profile distortion. Single turbine for piping DN 50 (2 in.) and smaller. Flow sensing turbine rotors shall be nonmetallic and not impaired by magnetic drag.
          2. Insertion-type complete with hot-tap isolation valves to enable sensor removal without water supply system shutdown.
          3. Sensing method shall be impedance sensing (nonmagnetic and nonphotoelectric).
          4. Volumetric Accuracy

±0.5% of reading at calibrated velocity

±1% of reading from 0.9 to 9 m/s (3 to 30 ft/s) (10:1 range)

±2% of reading from 0.12 to 6 m/s (0.4 to 20 ft/s) (50:1 range)

* + - * 1. Each sensor shall be individually calibrated and tagged accordingly against the manufacturer’s primary standards, which must be accurate to within 0.1% of flow rate and traceable to NIST.
        2. Maximum operating pressure of 2758 kPa (400 psi) and maximum operating temperature of 93.3°C (200°F) continuous (104.4°C [220°F] peak)
        3. All wetted metal parts shall be constructed of 316 stainless steel.
        4. Analog outputs shall consist of noninteractive zero and span adjustments, a DC linearly of 0.1% of span, voltage output of 0 to 10 VDC, and current output of 4 to 20 mA.
      1. Magnetic Flow-Tube Type Flowmeter
         1. Sensor shall be a magnetic flowmeter that utilizes Faraday’s Law to measure volumetric fluid flow through a pipe. The flowmeter shall consist of two elements, the sensor and the electronics. The sensor shall generate a measuring signal proportional to the flow velocity in the pipe. The electronics shall convert this EMF into a standard current output.
         2. Electric replacement shall not affect meter accuracy (electric units are not matched with specific sensors).
         3. Four-wire, externally powered, magnetic-type flow transmitter with adjustable span and zero, integrally mounted to flow tube.
         4. Output signal shall be a digital pulse proportional to the flow rate (to provide maximum accuracy and to handle abrupt changes in flow). Standard 4 to 20 mA or 0 to 10 VDC outputs may be used provided accuracy is as specified.
      2. Flow Tube
         1. ANSI class 1034 kPa (150 psig) steel
         2. ANSI flanges
         3. Protected with PTFE, PFA, or ETFE liner rated for 118.3°C (245°F) minimum fluid temperature
         4. Electrode and grounding material

316L stainless steel or Hastelloy C

Electrodes shall be fused to ceramic liner and not require o-rings.

* + - * 1. Electrical enclosure: NEMA 4, IP65, NEMA 7-9 as required
        2. Approvals

UL or CSA

NSF drinking-water approval for domestic water applications.

* + - * 1. Performance

Accuracy shall be ±0.5% of actual reading from 0.9 to 9 m/s (3 to 30 ft/s) flow velocities, and 2% from 0.012 to 0.9 m/s (0.04 to 3 ft/s).

Stability: 0.1% of rate over six months

Meter repeatability shall be ±0.1% of rate at velocities > 0.9 m/s (>3 ft/s).

Bidirectional capability as optional

* + - 1. Magnetic Insertion-Type Flowmeter
         1. Magnetic Faraday point velocity measuring device
         2. Insertion-type complete with hot-tap isolation valves to enable sensor removal without water supply system shutdown
         3. 4 to 20 mA transmitter proportional to flow or velocity
         4. Accuracy: Larger of 1% of reading and 0.6 m/s (0.2 ft/s)
         5. Flow range: 0.06 to 6 m/s (0.2 to 20 ft/s), bidirectional
         6. Each sensor shall be individually calibrated and tagged accordingly against the manufacturer’s primary standards, which must be accurate to within 0.1% of flow rate and traceable to NIST or other nationally recognized testing laboratory
      2. Vortex Shedding Flowmeter
         1. Output. 4 to 20 mA, 0 to 10 VDC, 0 to 5 VDC
         2. Maximum fluid temperature: 427°C (800°F)
         3. Wetted parts: stainless steel
         4. Housing: NEMA 4X, IP65
         5. Turndown: 25:1 minimum
         6. Accuracy: 0.5% of calibrated span for liquids, 1% of calibrated span for steam and gases
         7. Body: Wafer-style or ANSI flanged to match piping specification transit-time ultrasonic flowmeter
      3. Clamp-On Transit-time Ultrasonic Flowmeter
         1. Wide-beam transducer technology
         2. 4 to 20 mA transmitter proportional to flow or velocity
         3. Accuracy: 0.5% of reading in range 0.3 to 9 m/s (1 to 30 ft/s), 0.0003 m/s(0.001 ft/s) sensitivity
    1. Thermal Energy Meters
       1. Matched RTD, solid-state, or thermistor temperature sensors with a differential temperature accuracy of ±0.0833°C (0.15°F)
       2. Flowmeter:
       3. Unit accuracy of ±1% factory calibrated, traceable to NIST with certification
       4. NEMA 3, IP 54 enclosure
       5. Panel-mounted display
       6. UL listed
       7. Isolated 4 to 20 mA signals for energy rate and supply and return temperatures and flow
       8. Energy meter shall be equipped with an instantaneous flow and a totalized flow with a totalizer that can hold one month of data.
    2. Current Switches
       1. Current-operated switches shall be self-powered, solid-state with adjustable trip current. The switches shall be selected to match the current of the application and output requirements of the DDC system.
    3. Pressure Transducers
       1. Transducer shall have linear output signal. Zero and span shall be field adjustable.
       2. Transducer sensing elements shall withstand continuous operating conditions of positive or negative pressure 50% greater than calibrated span without damage.
       3. Water pressure transducer shall have stainless-steel diaphragm construction, proof pressure of 1034 kPa (150 psi) minimum. Transducer shall be complete with 4 to 20 mA output, required mounting brackets, and block and bleed valves.
       4. Water differential pressure transducer shall have stainless-steel diaphragm construction, proof pressure of 1034 kPa (150 psi) minimum. Overrange limit (differential pressure) and maximum static pressure shall be 2068 kPa (300 psi). Transducer shall be complete with 4 to 20 mA output, required mounting brackets, and five-valve manifold
    4. Differential-Pressure Type Switches (Air or Water Service)
       1. Shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum), NEMA 1, IP 20 enclosure, with scale range and differential suitable for intended application or as shown
    5. Pressure-Electric (PE) Switches
       1. Shall be metal or neoprene diaphragm actuated, operating pressure rated 0 to 175 kPa (0 to 25 psig), with calibrated scale set-point range of 14 to 125 kPa (2 to 18 psig) minimum, UL listed
       2. Provide one- or two-stage switch action SPDT, DPST, or DPDT, as required by application, electrically rated for pilot duty service (125 VA minimum) and/or for motor control.
       3. Shall be open type (panel-mounted) or enclosed type for remote installation. Enclosed type shall be NEMA 1 unless otherwise specified.
       4. Shall have a permanent indicating gage on each pneumatic signal line to PE switches
    6. Electropneumatic Transducers
       1. Electronic/pneumatic (E/P) transducer shall provide a proportional 20 to 100 kPa

(3 to 15 psig) output signal from either a 4 to 20 mA or 0 to 10 VDC analog control input.

* + - 1. E/P transducer shall be equipped with the following features:
         1. Separate span and zero adjustments
         2. Manual output adjustments
         3. Pressure gage assembly
         4. Feedback loop control
         5. Air consumption of 0.05 L/s (0.1 scfm) at midrange
    1. Local Control Panels
       1. All indoor control cabinets shall be fully enclosed NEMA 1 construction with (hinged door) key-lock latch and removable subpanels. A single key shall be common to all field panels and subpanels.
       2. Interconnections between internal and face-mounted devices shall be prewired with color- coded stranded conductors neatly installed in plastic troughs and/or tie-wrapped. Terminals for field connections shall be UL listed for 600 V service, individually identified per control/ interlock drawings, with adequate clearance for field wiring. Control terminations for field connection shall be individually identified per control drawings.
       3. Provide on/off power switch with overcurrent protection for control power sources to each local panel

## WIRING AND RACEWAYS

* + 1. General. Provide copper wiring, plenum cable, and raceways as specified in the applicable sections of the Electrical division of the specification. All insulated wire to be copper conductors, UL labeled for 90°C (194°F) minimum service

## FIBER -OPTIC CABLE SYSTEM

* + 1. Optical cable
    2. Connectors

## COMPRESSED AIR SUPPLY—PNEUMATIC

* + 1. Air Compressor
       1. Furnish and install a duplex temperature-control-type air compressor where indicated on plans. Oil carryover shall not exceed 4 ppm (ISO 8573 Class 5).
       2. Both compressors shall be mounted on a single ASME receiver tank, with the tank sized according to manufacturer recommendations, 115 L (30 gal) minimum, six starts per hour maximum. Each compressor is to be sized for no more than 33% runtime.
       3. Provide factory-installed duplex starter/automatic alternator package with separate motor feeds, arranged for automatic start of standby compressor.
       4. Provide OSHA belt guards, operating pressure switches, tank pressure gage, intake filters, ASME safety relief valves, check valves, shutoff valve, and vibration isolation pads for each air compressor unit.
       5. Provide electric-solenoid-type (normally closed) automatic receiver tank drain valve with built-in timers for operating frequency and duration.
    2. Refrigerated Air Dryer
       1. Provide continuously operating, hermetic compressor refrigerated type air dryer, UL listed, sized for maximum dew point of 9.5°C (15°F) with 38°C (100°F) saturated inlet air at

550 kPa (80 psig) at maximum rated flow.

* + - 1. Dryer package shall include operating/failure status indication, manual bypass service valve, inlet and outlet pressure gages, and automatic condensate drain trap with manual override.
    1. Regenerative Desiccant Compressed Air Dryer
       1. Unit shall be wall-mounted, complete with two drying towers containing desiccant beds sized to ensure that air velocity across the desiccant bed is not greater than 0.3 m/s (60 fpm) at 700 kPa (100 psig). Bed shall be sized so that the effects of desiccant aging during the first year are negated. Each tower shall be furnished with fill and drain ports to facilitate desiccant replacement.
       2. Unit shall be complete with on/off switch, solid-state timer, control valves, and check valves. Purge air shall be exhausted through mufflers to reduce noise levels.
       3. Unit shall have a 20.7 kPa (3 psi) maximum pressure drop and provide dry air with a 40°C (40°F) dew point.
       4. Unit shall be sized to match required air consumption, 2.5 L/s (5 cfm) minimum.
    2. Filter and PRV Station
       1. Provide aerosol-coalescing-type auto-drain, submicron air filter assembly with replaceable element, 98% efficient for solids 0.3 µm and larger, with 99% efficient oil removal at rated capacity. Furnish with manual filter bypass and shutoff valves, upstream and downstream pressure gages, and one spare filter element.
       2. Provide relieving type pressure-reducing valves suitable for temperature control service sized for rated system capacity, with the following:
          1. ASME-rated safety relief valve on low-pressure side, factory set at 172.4 kPa (25 psig) maximum
          2. Control pressure gage on inlet and outlet
          3. Valved bypass
          4. Particle filter
    3. Tubing
       1. Copper. Provide ACR hard-drawn seamless copper tubing.
       2. Polyethylene. Provide type FR plenum rated polyethylene tubing. Tubing shall be rated for a maximum operating pressure of 200 kPa (30 psi) at 80°C (175°F), with an ambient operating temperature range of 13°C (10°F) to 65°C (150°F). Plastic tubing shall have the burning characteristics of linear low-density polyethylene tubing, shall be self-extinguishing when tested in accordance with ASTM D 635, shall have UL 94 V-2 flammability classification and shall withstand stress cracking when tested in accordance with ASTM D 1693. Plastic-tubing bundles shall be provided with mylar barrier and flame-retardant polyethylene jacket.

# EXECUTION

## Section Includes

* + 1. Examination
    2. Protection
    3. Coordination
    4. General Workmanship
    5. Field Quality Control
    6. Existing Equipment
    7. Wiring
    8. Communication Wiring
    9. Fiber Optic Cable System
    10. Control Air Tubing
    11. Installation of Sensors
    12. Flow Switch Installation
    13. Actuators
    14. Warning Labels
    15. Identification of Hardware and Wiring
    16. Controllers
    17. Programming
    18. BAS Checkout and Testing
    19. BAS Demonstration and Acceptance
    20. Cleaning
    21. Training
    22. Sequences of Operation
    23. Control Valve Installation
    24. Control Damper Installation
    25. Smoke Damper Installation
    26. Duct Smoke Detection
    27. Controls Communication Protocol
    28. Start-Up and Checkout Procedures

## EXAMINATION

* + 1. Contract Drawings and Site Examination
       1. Examine the mechanical, electrical, and other trade drawings to ensure that the work under this contract can be satisfactorily carried out. Report any discrepancies to the DCC representative prior to submission of bid.
       2. Any drawings supplied by the BAS designer and other engineers of record are performance drawings, are diagrammatic in nature, and are intended to convey the scope of work and to indicate general arrangement and approximate location of apparatus, fixtures, and pipe runs. The drawings do not intend to show architectural and structural details.
       3. Do not scale drawings. Obtain accurate dimensions by site measurement.
       4. Not all required offsets, fittings, and accessories are shown in the drawings. Investigate structural and finish conditions affecting this work and arrange the work accordingly, providing such fittings, valves, and accessories required to meet the conditions. Conserve head room and interfere as little as possible with the free use of space.
       5. Examine the site and local conditions and verify that the supplied equipment is suitable for its intended use in the new/renovation construction.
    2. Visit and inspect the site of the Work to verify location and elevation of existing services that affect work of this contract (water, electrical, sanitary, ductwork, etc.) before proceeding with work.

## PROTECTION

* + 1. The BAS contractor shall protect all work and material from damage by their work or employees and shall be liable for all damage thus caused.
    2. The BAS contractor shall be responsible for work and equipment until finally inspected, tested, and accepted. The contractor shall protect any material that is not immediately installed. The contractor shall close all open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

## COORDINATION

* + 1. Where the mechanical work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment. If the contractor installs their work before coordinating with other trades, so as to

cause any interference with work of other trades, the contractor shall make the necessary changes in their work to correct the condition without extra charge.

* + 1. Coordinate and schedule work with all other work in the same area, or with work that is dependent on other work, to facilitate mutual progress.

## TEST AND BALANCE

* + 1. The controls contractor shall furnish a single set of all tools necessary for the test and balance (TAB) contractor to interface to the BAS for TAB purposes.
    2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of four hours.
    3. In addition, the contractor shall provide a qualified technician to assist in the TAB process, considering the number of equipment to be balanced.
    4. The tools used during the process will be returned at the completion of the TAB.
    5. Duct smoke detectors required for air-handler shutdown are supplied under Division 26, “Electrical” of the project specification. The contractor shall interlock smoke detectors to air handlers for shutdown as described in Article 3.22, “Sequences of Operation.”
    6. Smoke dampers and actuators required for duct smoke isolation are provided under a section of the Mechanical division of the project specification. The contractor shall interlock these dampers to the air handlers as described in Article 3.22, “Sequences of Operation.”
    7. Fire/smoke dampers and actuators required for fire-rated walls are provided under another section of the Mechanical division of the specification. Control of these dampers shall be by Division 26, “Electrical,” of the project specification. The contractor shall provide control air to the dampers.
    8. Coordination with Controls Specified in Other Sections or Divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the BAS specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:
    9. All communication media and equipment shall be provided as specified in Article 2.3, “Communication,” of this specification.
    10. Each supplier of a control’s product is responsible for the configuration, programming, start-up, and testing of that product to meet the sequences of operation described in this section.
    11. The contractor shall coordinate and resolve any incompatibility issues that arise between the control products provided under this section and those provided under other sections or divisions of this specification.
    12. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described.
    13. The BAS contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

## GENERAL WORKMANSHIP

* + 1. Install equipment, piping, and wiring/raceway parallel to building lines (i.e., horizontal, vertical, and parallel to walls) wherever possible.
    2. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.
    3. Install all equipment in readily accessible locations as defined by Chapter 1, Article 100, Part A of the National Electrical Code (NEC).
    4. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.
    5. All equipment, installation, and wiring shall comply with acceptable industry specifications and standards for performance, reliability, and compatibility and be executed in strict adherence to local codes and standard practices.

## FIELD QUALITY CONTROL

* + 1. All work, materials, and equipment shall comply with the rules and regulations of applicable local, state, and federal codes and ordinances as identified in Part 1, “General,” of this specification.
    2. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.
    3. Contractor shall have work inspected by local and/or state AHJs over the work.

## EXISTING EQUIPMENT

* + 1. Wiring. SELECT OR EDIT {The contractor may reuse any abandoned wires. The integrity of the wire and its proper application to the installation are the responsibility of the contractor. The wire shall be properly identified and tested in accordance with this specification. Unused or redundant wiring must be properly identified as such.} {Interconnecting control wiring shall be removed and become the property of the contractor unless specifically noted or shown to be reused.}
    2. Pneumatic Tubing. SELECT OR EDIT {The contractor may reuse any redundant pneumatic tubing. The integrity of the tubing and its proper application to the installation are the responsibility of the contractor. The tubing shall be properly identified and of material in accordance with this specification. Unused or redundant tubing must be removed or, where this is not possible, properly identified.} {Interconnecting pneumatic control tubing shall be removed and become the property of the contractor unless specifically noted or shown to be reused.}. If pressurized pneumatic tubing is used in the work, contractor shall test all the tubing at 206 kPa (30 psi) for ten minutes. The owner reserves the right to witness any and all testing. Repair or replace all tubing that has failed this test. Submit report results via the submittal process.
    3. Local Control Panels. SELECT OR EDIT {The contractor may reuse any existing local control panel to locate new equipment. All redundant equipment within these panels must be removed. Panel face cover must be patched to fill all holes caused by removal of unused equipment or replaced with new.} {No existing panels are to be reused. Remove and deliver to owner.}

{Existing panels become the property of the contractor.} {Salvage, recondition, and reuse existing devices and cabinets as noted. Relocate as shown.}. Contractor shall consider verification of UL rating for reused panels; refer to scope of work.

* + 1. Unless otherwise directed, the contractor is not responsible for the repairs or replacement of existing energy equipment and systems, valves, dampers, or actuators. Should the contractor find existing equipment that requires maintenance, the BAS designer is to be notified immediately.
    2. Temperature Sensor Wells. The contractor shall examine existing wells for corrosion and other damage. The contractor may reuse any existing wells in piping for temperature sensors as determined by the contractor. These wells shall be modified as required for proper fit of new sensors.
    3. Indicator Gages. Where these devices remain and are not removed, they must be made operational and recalibrated to ensure reasonable accuracy. Maintain the operation of existing pneumatic transmitters and gages.
    4. Room Thermostats. SELECT OR EDIT {Salvage, recondition, and reuse.} {Deliver to owner.}

{Shall be removed and become the property of the contractor unless otherwise noted}.

* + 1. Electronic Sensors and Transmitters. Unless specifically noted otherwise, SELECT OR EDIT

{remove and deliver to the owner} {become the property of the contractor}.

* + 1. Controllers and Auxiliary Electronic Devices. SELECT OR EDIT {Deliver to the owner.} {Salvage, recondition, and reuse.} {Become the property of the contractor.}
    2. Pneumatic Controllers, Relays, and Gages: SELECT OR EDIT {Deliver to owner.} {Become the property of the contractor.}
    3. Damper Actuators, Linkages, and Appurtenances. SELECT OR EDIT {Deliver to owner.} {Salvage, recondition, and reuse.} {Become the property of the contractor.}
    4. Control Valves. SELECT OR EDIT {Replace with new.} {Salvage, recondition, and reuse.}

{Become the property of the contractor.}

* + 1. Control Compressed Air System. SELECT OR EDIT {Deliver to owner and replace with new system.} {Salvage, recondition, and reuse.} {Becomes the property of the contractor, unless otherwise noted.}
    2. The mechanical system must remain in operation as described in the scope of work. Scheduled shutdowns must be submitted and approved with at least a 24 hour notice. Unscheduled shutdowns shall be minimized and contractor may be subject to back charges if impacting other trades. No modifications to the system shall cause the mechanical system to be shut down for more than 15 minutes or to fail to maintain space comfort conditions during any such period. Perform cutover of controls that cannot meet these conditions outside of those hours.
    3. The scheduling of equipment through existing or temporary time clocks or BAS shall be maintained throughout the BAS installation.
    4. Install control panels where indicated on floor plan drawings and coordinate adequate power, clearances, and access. Update record drawings upon changes to construction documents.
    5. Modify existing starter control circuits, if necessary, to provide hand/off/auto control of each starter controlled. If new starters or starter control packages are required, these shall be included as part of this contract. Provide elementary drawings of all starter circuits and update record documents.
    6. Coordinate the patching of holes and finish to match existing walls with the prime contractor and/or architect.
    7. Penetrations in rated walls and enclosures must be approved by architect prior to beginning the work.
    8. Coordinate the sealing of openings in fire-rated assemblies with prime contractor and/or architect.

## WIRING

* + 1. All control and interlock wiring shall comply with national and local electrical codes and the Electrical division of this specification. Where the requirements of this section differ from those in Division 26, the requirements of this section may take precedence. The engineer of record must approve any deviations between this specification and Division 26 specifications.
    2. All NEC Class 1 (line voltage) wiring shall be UL Listed in approved raceway according to NEC and Electrical division requirements.
    3. All low-voltage wiring shall meet NEC Class 2 requirements. (Low-voltage power circuits shall be subfused when required to meet Class 2 current limit.)
    4. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return-air plenums, approved cables not in raceway may be used provided that cables are UL listed for the intended application. For example, cables used in ceiling plenums shall be UL listed specifically for that purpose.
    5. All wiring in mechanical, electrical, or service rooms—or where subject to mechanical damage—shall be installed in raceway at levels below 3 m (10 ft).
    6. Do not install Class 2 wiring in raceway containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g., relays and transformers).
    7. Do not install wiring in raceway containing tubing.
    8. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 3 m (10 ft) intervals. J hooks are allowed only with permission of the BAS designer.
    9. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical race- ways, piping, or ceiling suspension systems.
    10. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to- wire connections shall be at a terminal block.
    11. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.
    12. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.
    13. All wiring shall be installed as continuous lengths. No splices are permitted between termination points.
    14. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.
    15. Size of raceway and size and type of wire shall be the responsibility of the contractor, in keeping with the manufacturer’s recommendations and NEC requirements, except as noted elsewhere.
    16. Include one pull-string in each raceway 2.5 cm (1 in.) or larger.
    17. Use color-coded conductors throughout with conductors of different colors as approved by the engineer or noted elsewhere in the specifications.
    18. Control and status relays are to be located in designated enclosures only. These enclosures include packaged-equipment control-panel enclosures unless they also contain Class 1 starters.
    19. Conceal all raceways, except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15 cm (6 in.) from high-temperature equipment (e.g., steam pipes or flues).
    20. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull-boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.
    21. Adhere to Electrical division requirements where raceway crosses building expansion joints.
    22. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of all vertical raceways.
    23. The contractor shall terminate all control and/or interlock wiring and shall maintain updated (as- built) wiring diagrams with terminations identified at the job site.
    24. Flexible metal raceways and liquid-tight, flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than 16 mm (0.5 in.) electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.
    25. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.
    26. Contractor is responsible for installing wiring and landing of final terminations of devices supplied and installed by others unless otherwise specified.

## COMMUNICATION WIRING

* + 1. The BAS contractor shall adhere to the items listed in the wiring section of the specification.
    2. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer’s installation recommendations for all communication cabling.
    3. Do not install communication wiring in raceway and enclosures containing Class 1 or other Class 2 wiring.
    4. Maximum pulling, tension, and bend radius for cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.
    5. Contractor shall verify the integrity of the entire network following the cable installation. Use appropriate test measures for each particular cable.
    6. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lighting arrestor shall be installed according to the manufacturer’s instructions.
    7. All runs of communication wiring shall be unspliced length when that length is commercially available.
    8. All communication wiring shall be labeled to indicate origination and destination data.
    9. Grounding of coaxial cable shall be in accordance with NEC regulations article on communications circuits, cable, and protector grounding.
    10. Contractor is responsible for installing wiring and landing of final terminations of devices supplied and installed by others unless otherwise specified.

## FIBER OPTIC CABLE SYSTEM

* + 1. Maximum pulling tensions, as specified by the cable manufacturer, shall not be exceeded during installation. Postinstallation residual cable tension shall be within cable manufacturer’s specifications.
    2. All cabling and associated components shall be installed in accordance with manufacturers’ instructions. Minimum cable and unjacketed fiber bend radii, as specified by cable manufacturer, shall be maintained.

## CONTROL AIR AND IMPULSE TUBING

* + 1. 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.
    2. Vertical risers shall be ridged copper.
    3. Sensor tubing shall be sized by the contractor. Locate sensors to minimize tubing runs at the expense of increased wiring distances.
    4. 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.
    5. 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.
    6. 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.
    7. Purge tubing with dry, oil-free compressed air nitrogen (if approved by safety department) before connecting control instruments.
    8. 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:

* + - * 1. FR tubing shall be enclosed in metal raceway when required by local code.
        2. Quantity of FR tubing per plenum volume of plenum space shall not exceed manufacturer’s published data for Class 1 installation.
      1. (Exposed) Use hard-drawn ACR copper or FR plastic in metal raceway.
    1. 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.
    2. Pneumatic tubing shall not be run in raceway containing electrical wiring.
    3. 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.
    4. All control air piping shall be installed in a neat and workmanlike manner parallel to building lines with adequate support.
    5. 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.
    6. For air pressures greater than 200 kPa (30 psig), compression- or solder-type connection shall be used.
    7. 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.
    8. Brass-barbed fittings shall be used at copper-to-FR-tubing junctions. Plastic slipped-over copper tubing is not acceptable.
    9. 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.

## INSTALLATION OF SENSORS

* + 1. Install sensors in accordance with the manufacturer’s recommendations.
    2. Mount sensors rigidly and adequately for the environment within which the sensor operates.
    3. Room temperature sensors shall be installed on concealed junction boxes properly supported by the wall framing.
    4. All wires attached to sensors shall be air-sealed in their raceways or in the wall to stop air transmitted from other areas affecting sensor readings.
    5. Sensors used in mixing plenums and hot and cold decks shall be of the averaging type. Averaging sensors shall be installed in a serpentine manner vertically across the duct. Each bend shall be supported with a capillary clip.
    6. 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.
    7. All pipe-mounted temperature sensors shall be installed in wells. Install all liquid temperature sensors with heat-conducting fluid in thermal wells.
    8. Install outdoor air temperature sensors on north wall, complete with sun shield at designated location
    9. Differential Air Static Pressure
       1. Supply-Duct Static Pressure. Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the high-pressure tap tubing of the corresponding building static pressure sensor (if applicable) or to the location of the duct high-pressure tap and leave open to the plenum.
       2. Return Duct Static Pressure. Pipe the high-pressure tap to the duct using a pitot tube. Pipe the low-pressure port to a tee in the low-pressure tap tubing of the corresponding building static pressure sensor. Provide a device that gives a stable reference to the low side of the static pressure reference to minimize fluctuations in the differential static pressure reading for the building.
       3. 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.
       4. The piping to the pressure ports on all pressure transducers shall contain a capped test port located adjacent to the transducer.
       5. 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.
       6. All air and water differential pressure sensors shall have gage tees mounted adjacent to the taps. Water gages shall also have shutoff valves installed before the tee.

## FLOW SWITCH INSTALLATION

* + 1. Use correct paddle for pipe diameter.
    2. Adjust flow switch in accordance with manufacturer’s instructions.

## ACTUATORS

* + 1. Mount and link control damper actuators according to manufacturer’s instructions.
    2. 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.
    3. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
    4. Provide all mounting hardware and linkages for actuator installation.
    5. 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.
    6. 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 (jackshafting) in lieu of blade-to-blade linkages or shaft coupling when driving axially aligned damper sections.

## WARNING LABELS

* + 1. Permanent warning labels shall be affixed to all equipment that can be automatically started by the BAS.
    2. Labels shall use white lettering (12-point type [4.25 mm] or larger) on a red background.
    3. Warning labels shall read as follows:

CAUTION

This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to OFF position before servicing.

## IDENTIFICATION OF HARDWARE AND WIRING

* + 1. All wiring and cabling, including that within factory-fabricated panels, shall be labeled at each end within 5 cm (2 in.) of termination with the BAS address or termination number.
    2. All pneumatic tubing shall be labeled at each end within 5 cm (2 in.) of termination with a descriptive identifier.
    3. Permanently label or code each point of field terminal strips to show the instrument or item served.
    4. Identify control panels with minimum 1 cm (0.5 in.) letters on laminated plastic nameplates.
    5. Identify all other control components with permanent labels. All plug-in components shall be labeled such that removal of the component does not remove the label.
    6. Identify room sensors relating to terminal box or valves with nameplates.
    7. Manufacturers’ nameplates and UL or CSA labels are to be visible and legible after equipment is installed.
    8. Identifiers shall match record documents.

## CONTROLLERS

* + 1. Provide a separate controller for each AHU or other HVAC system. A BAS controller may control more than one system provided that all points associated with the system are assigned to the same BAS controller. Points used for control-loop reset, such as outdoor air or space temperature, are exempt from this requirement.
    2. Building controllers and custom application 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. Future use of spare capacity shall require providing the field device, field wiring, point database definition, and custom software. No additional controller boards or point modules shall be required to implement use of these spare points.

## PROGRAMMING

* + 1. 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.
    2. Point Naming. System point names shall be modular in design, allowing easy operator interface without the use of a written point index.
    3. 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.
    4. 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.
    5. 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.
    6. 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.
    7. 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:
          1. Text-based

Must provide actions for all possible situations

Must be modular and structured

Must be commented

* + - * 1. Graphic-based

Must provide actions for all possible situations

Must be documented

* + - * 1. Parameter-based

Must provide actions for all possible situations

Must be documented

* + - 1. Submit sample programming of representative systems for approval by BAS designer.
    1. 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.

## BAS CHECKOUT AND TESTING

* + 1. Start-up Testing. All testing listed in this article shall be performed by the contractor and shall make up part of the necessary verification of an operating BAS. This testing shall be completed before the owner’s representative is notified of the system demonstration.
    2. See commissioning specification {may be prepared by the BAS designer or the project CxA}.
       1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
       2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
       3. Enable the BASs and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers’ recommendations.
       4. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
       5. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
       6. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops and optimum start/stop routines.
    3. Alarms and Interlocks
       1. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
       2. Interlocks shall be tripped using field contacts to check the logic and to ensure that the failsafe condition for all actuators is in the proper direction.
       3. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action.

## BAS DEMONSTRATION AND ACCEPTANCE

* + 1. Demonstration
       1. Prior to acceptance, the BAS shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the contractor has completed the installation, started up the system, and performed their own tests.
       2. The tests described in this section are to be performed in addition to the tests that the contractor performs as a necessary part of the installation, start-up, and debugging process and as specified in Article 3.20, “BAS Checkout and Testing,” of this specification. The BAS designer will be present to observe and review these tests. The BAS designer shall be notified at least ten days in advance of the start of the testing procedures.
       3. The demonstration process shall follow that approved in Article 1.14, “Submittals.” The approved checklists and forms shall be completed for all systems as part of the demonstration.
       4. The contractor shall demonstrate actual field operation of each control and sensing point for all modes of operation, including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power.
       5. The purpose of failure modes is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the contractor.
       6. As each control input and output is checked, a log shall be completed showing the date, technician’s initials, and any corrective action taken or needed.
       7. Demonstrate compliance with Article 1.9.
       8. Demonstrate compliance with sequences of operation through all modes of operation.
       9. Demonstrate complete operation of operator interface.
       10. Additionally, the following items shall be demonstrated:
           1. DDC Loop Response. The contractor shall supply trend data output in a graphical form showing the step response of each DDC loop. The test shall show the loop’s response to a change in set point, which represents a change of actuator position of at least 25% of its full range. The sampling rate of the trend shall be from ten seconds to three minutes, depending on the speed of the loop. The trend data shall show for each sample the set point, actuator position, and controlled variable values. Any loop that yields unreasonably underdamped or overdamped control shall require further tuning by the contractor.
           2. Demand Limiting. The contractor shall supply a trend data output showing the action of the demand-limiting algorithm. The data shall document the action on a minute-by-min- ute basis over at least a 30-minute period. Included in the trend shall be building kilo- watts, demand-limiting set point, and the status of sheddable equipment outputs.
           3. Optimum Start/Stop. The contractor shall supply a trend data output showing the capability of the algorithm. The change-of-value or change-of-state trends shall include the output status of all optimally started and stopped equipment, as well as temperature sensor inputs of affected areas.
           4. Interface to the building fire-alarm system
           5. Operational logs for each system that indicate all set points, operating points, valve positions, mode, and equipment status shall be submitted to the architect/BAS designer. These logs shall cover three 48-hour periods and have a sample frequency of not more than ten minutes. The logs shall be provided in both printed and disk formats.
       11. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests.
    2. Acceptance
       1. All tests described in this specification shall have been performed to the satisfaction of both the BAS designer and owner prior to the acceptance of the BAS as meeting the requirements of completion. Any tests that cannot be performed due to circumstances beyond the control of the contractor may be exempt from the completion requirements if stated as such in writing by the BAS designer. Such tests shall then be performed as part of the warranty.
       2. The system shall not be accepted until all forms and checklists completed as part of the demonstration are submitted and approved as required in Article 1.10, Submittals.

## CLEANING

* + 1. 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.
    2. 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.
    3. 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

## TRAINING

* + 1. Provide a minimum of four on-site or classroom training sessions, three days each, throughout the contract period for personnel designated by the owner.
    2. Provide two additional training sessions at 6 and 12 months following building turnover. Each session shall be three days in length and must be coordinated with the building owner.
    3. Train the designated staff of the owner and their representative to enable them to do the following:
       1. Day-to-day Operators
          1. Proficiently operate the system
          2. Understand BAS architecture and configuration
          3. Understand system components
          4. Understand system operation, including BAS device control and optimizing routines (algorithms)
          5. Operate the workstation and peripherals
          6. Log on and off the system
          7. Access graphics, point reports, and logs
          8. Adjust and change system set points, time schedules, and holiday schedules
          9. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
          10. Understand system drawings and operations and maintenance (O&M) manual
          11. Access data from controllers and application-specific controllers (ASCs)
          12. Operate portable operator’s terminals
       2. Advanced Operators
          1. Make and change graphics on the workstation
          2. Create, delete, and modify alarms, including annunciation and routing of these
          3. Create, delete, and modify point trend logs and graph or print these both on an ad-hoc basis and at user-definable time intervals
          4. Create, delete, and modify reports
          5. Add, remove, and modify system’s physical points
          6. Create, modify, and delete programming
          7. Add panels when required
          8. Add operator interface stations
          9. Create, delete, and modify system displays, both graphical and other
          10. Perform BAS field checkout procedures
          11. Perform BAS controller unit O&M procedures
          12. Perform workstation and peripheral O&M procedures
          13. Perform BAS diagnostic procedures
          14. Configure hardware including PC boards, switches, communication, and I/O points
          15. Maintain, calibrate, troubleshoot, diagnose, and repair hardware
          16. Adjust, calibrate, and replace system components
       3. System Managers/Administrators
          1. Maintain software and prepare backups
          2. Interface with job-specific, third-party operator software
          3. Add new users and understand password security procedures
          4. Provide course outline and materials in accordance with Article 1.14, “Submittals,” of this specification. The instructor(s) shall provide one copy of training material per student.
          5. The instructor(s) shall be factory-trained instructors experienced in presenting this material.
          6. Classroom training shall be done using a network of working controllers representative of the installed hardware

## SEQUENCES OF OPERATION

* + 1. {Provide operation as shown on drawings.}

## CONTROL VALVE INSTALLATION

* + 1. Valve submittals shall be coordinated for type, quantity, size, and piping configuration to ensure compatibility with pipe design.
    2. 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.
    3. Valves shall be installed in accordance with the manufacturer’s recommendations.
    4. 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.
    5. Isolation valves shall be installed so that the control-valve body may be serviced without draining the supply/return-side piping system. {Note to designer: This must also be shown.} Unions shall be installed at all connections to screw-type control valves.
    6. 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.

## CONTROL DAMPER INSTALLATION

* + 1. Damper submittals shall be coordinated for type, quantity, and size to ensure compatibility with sheet metal design.
    2. 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.
    3. 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.
    4. 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.
    5. 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.)
    6. 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.
    7. Provide a visible and accessible indication of damper position on the drive shaft end.
    8. Support ductwork in area of damper when required to prevent sagging due to damper weight.
    9. After installation of low-leakage dampers with seals, caulk between frame and duct or opening to prevent leakage around perimeter of damper.

## SMOKE DAMPER INSTALLATION

* + 1. The contractor shall coordinate all smoke and smoke/fire damper installation, wiring, and checkout to ensure that these dampers function properly and that they respond to the proper fire-alarm system general, zone, and/or detector trips. The contractor shall immediately report any discrepancies to the BAS designer no less than two weeks prior to inspection by the code authority having jurisdiction.

## CONTROLS COMMUNICATION PROTOCOL

* + 1. General. The information to be communicated between the BAS and these controls shall be in the standard object format as defined by open protocol. Controllers shall communicate with other open protocols and BAS objects on the network using the protocol specific service as defined by protocol selected. {See appendix asked for a reference to open protocol guideline specifications language for LAN technologies that are available.}
    2. Distributed Processing. The controller shall be capable of stand-alone operation and shall continue to provide control functions without being connected to the network.
    3. I/O Capacity. The controlled shall contain sufficient I/O capacity to control the target system.
    4. Communication. The controller shall reside on BAS open protocol network using the device- level protocol. Each network controller shall be connected to one building controlled.
    5. The controller shall have a network connection for a laptop computer or a portable operator’s tool.
    6. Environment. The hardware shall be suitable for the anticipated ambient conditions.
    7. Controllers used outdoors and/or in wet ambient condition shall be mounted within waterproof enclosures and shall be rated for operation at 40°C to 65°C (104°F to 150°F).
    8. Controllers used in conditioned space shall be mounted in dust-proof enclosure and shall be rated for operation at 0°C to 50°C (32°F to 120°F).
    9. Serviceability. Provide diagnostic LED for power, communication, and processors. All wiring connections shall be made to field removable, modular terminal strips or to termination card connected by ribbon cable.
    10. Memory. The controller shall maintain all BIOS and programming information in the event of a power loss for at least 90 days.
    11. Immunity to Power and Noise
        1. Controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80%. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).
    12. Transformer. Power supply for the controller must be rated at a minimum of 120% ASC power consumption and shall be fused or current-limiting type.

## START-UP AND CHECKOUT PROCEDURES

* + 1. Start up, check out, and test all hardware and software, and verify communication between all components.
    2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
    3. Verify that all analog and binary input/output points read properly.
    4. Verify alarms and interlocks.
    5. Verify operation of the integrated system