

SECTION 23 09 23
DIRECT DIGITAL CONTROL SYSTEM FOR HVAC

Addendum #1
06/24/16

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Provide a direct-digital control system as indicated on the project documents, point list, interoperability tables, drawings and as described in these specifications. Include a complete and working direct-digital control system. Include all engineering, programming, controls and installation materials, installation labor, commissioning and start-up, training, final project documentation and warranty.
1. The direct-digital control system(s) shall consist of high-speed, peer-to-peer network of DDC controllers, a control system server, and an Engineering Control Center. Provide a remote user using a standard web browser to access the control system graphics and change adjustable setpoints with the proper password.
 2. The direct-digital control system(s) shall be native BACnet. All new workstations, controllers, devices and components shall be listed by BACnet Testing Laboratories. All new workstations, controller, devices and components shall be accessible using a Web browser interface and shall communicate exclusively using the ASHRAE Standard 135 BACnet communications protocol without the use of gateways, unless otherwise allowed by this Section of the technical specifications, specifically shown on the design drawings and specifically requested otherwise by the VA.
 - a. If used, gateways shall support the ASHRAE Standard 135 BACnet communications protocol.
 - b. If used, gateways shall provide all object properties and read/write services shown on VA-approved interoperability schedules.
 3. The work administered by this Section of the technical specifications shall include all labor, materials, special tools, equipment, enclosures, power supplies, software, software licenses, Project specific software configurations and database entries, interfaces, wiring, tubing, installation, labeling, engineering, calibration, documentation, submittals, testing, verification, training services, permits and licenses, transportation, shipping, handling, administration, supervision, management, insurance, Warranty, specified services and items required for complete and fully functional Controls Systems.
 4. The control systems shall be designed such that each mechanical system shall operate under stand-alone mode. The contractor administered by this Section of the technical specifications shall provide controllers for each mechanical system. In the event of a network communication failure, or the loss of any other controller, the control system shall continue to operate independently. Failure of the ECC shall have no effect on the field controllers, including those involved with global strategies.
 5. The control system shall accommodate 1 laptop computer to be located in HVAC Shop Building 235. The control system shall accommodate 10 web-based Users simultaneously, and the access to the system should be limited only by operator password.
 6. Connect the new work to the existing ECC system or operator workstation manufactured by Johnson Controls, Inc. Metasys System located in the Refrigeration Shop. The existing CPU/Monitor,

printer and other peripherals may be used to form a single operator workstation. New system including interface to existing systems and equipment shall operate and function as one complete system including one database of control point objects and global control logic capabilities. Facility operators shall have complete operations and control capability over all systems, new and existing including: monitoring, trending, graphing, scheduling, alarm management, global point sharing, global strategy deployment, graphical operations interface and custom reporting as specified. Modify the existing ECC, if necessary, to accommodate the additional control points.

- B. Some products are furnished but not installed by the contractor administered by this Section of the technical specifications. The contractor administered by this Section of the technical specifications shall formally coordinate in writing and receive from other contractors formal acknowledgements in writing prior to submission the installation of the products. These products include the following:
 - 1. Control valves.
 - 2. Flow switches.
 - 3. Flow meters.
 - 4. Sensor wells and sockets in piping.
 - 5. Terminal unit controllers.
- C. Some products are installed but not furnished by the contractor administered by this Section of the technical specifications. The contractor administered by this Section of the technical specifications shall formally coordinate in writing and receive from other contractors formal acknowledgements in writing prior to submission the procurement of the products. These products include the following:
 - 1. Factory-furnished accessory thermostats and sensors furnished with unitary equipment.
- D. Some products are not provided by, but are nevertheless integrated with the work executed by, the contractor administered by this Section of the technical specifications. The contractor administered by this Section of the technical specifications shall formally coordinate in writing and receive from other contractors formal acknowledgements in writing prior to submission the particulars of the products. These products include the following:
 - 1. Fire alarm systems. If zoned fire alarm is required by the project-specific requirements, this interface shall require multiple relays, which are provided and installed by the fire alarm system contractor, to be monitored.
 - 2. Advanced utility metering systems. These systems may take information from the control system or its component meters and sensors. There is no command or control action from the advanced utility monitoring system on the control system however.
 - 3. Boiler controls. These controls, if not native BACnet, will require a BACnet Gateway.
 - 4. Terminal units' velocity sensors
 - 5. Variable frequency drives. These controls, if not native BACnet, will require a BACnet Gateway.
 - 6. The following systems have limited control (as individually noted below) from the ECC:
 - a. Constant temperature rooms: temperature out of acceptable range and status alarms.

b. Domestic water heating systems: low temperature, high temperature and status alarms. Responsibility Table:

Work/Item/System	Furnish	Install	Low Voltage Wiring	Line Power
Control system low voltage and communication wiring	23 09 23	23 09 23	23 09 23	N/A
Terminal units	23	23	N/A	26
Controllers for terminal units	23 09 23	23	23 09 23	16
LAN conduits and raceway	23 09 23	23 09 23	N/A	N/A
Automatic dampers (not furnished with equipment)	23 09 23	23	N/A	N/A
Automatic damper actuators	23 09 23	23 09 23	23 09 23	23 09 23
Manual valves	23	23	N/A	N/A
Automatic valves	23 09 23	23	23 09 23	23 09 23
Pipe insertion devices and taps, flow and pressure stations.	23	23	N/A	N/A
Thermowells	23 09 23	23	N/A	N/A
Current Switches	23 09 23	23 09 23	23 09 23	N/A
Control Relays	23 09 23	23 09 23	23 09 23	N/A
Power distribution system monitoring interfaces	23 09 23	23 09 23	23 09 23	26
Chiller controls interface with control system	23	23	23 09 23	26
All control system nodes, equipment, housings, enclosures and panels.	23 09 23	23 09 23	23 09 23	26
Smoke detectors	28 31 00	28 31 00	28 31 00	28 31 00
Fire Dampers	23	23	N/A	N/A
Water treatment system	23	23	23	26
VFDs	23 73 00	23	23 09 23	26
Split System A/C Unit field-mounted controls	23	23 09 23	23 09 23	26
Control system interface with CRU A/C controls	23 09 23	23 09 23	23 09 23	26
Fire Alarm shutdown relay interlock wiring	28	28	28	26
Control system monitoring of fire alarm smoke control relay	28	28	23 09 23	28
Unit Heater controls (not furnished with equipment)	23 09 23	23 09 23	23 09 23	26
Starters, HOA switches	23	23	N/A	26

- E. This facility's existing direct-digital control system is manufactured by Johnson Controls and its ECC is located at Building 7 Boiler Plant. The existing system's top-end communications is via Workstation in Building 71 AC Shop. The contractor administered by this Section of the technical specifications shall observe the capabilities, communication network, services, spare capacity of the existing control system and

its ECC prior to beginning work.

1. Provide a new BACnet ECC, communications network, and controllers. Provide a programmable internetworking gateway allowing for real-time communication between the existing direct-digital control system and the new BACnet control system. Real-time communication shall provide all object properties and read/write services shown on VA-approved interoperability schedules. The contractor administered by this Section of the technical specifications shall provide all necessary investigation and site-specific programming to execute the interoperability schedules.
 - a. The combined system shall operate and function as one complete system including one database of control point objects and global control logic capabilities. Facility operators shall have complete operations and control capability over all systems, new and existing including; monitoring, trending, graphing, scheduling, alarm management, global point sharing, global strategy deployment, graphical operations interface and custom reporting as specified.
- F. This campus has standardized on an existing standard ASHRAE Standard 135, BACnet/IP Control System supported by a preselected controls service company. This entity is referred to as the "Control System Integrator" in this Section of the technical specifications. The Control system integrator is responsible for ECC system graphics and expansion. It also prescribes control system-specific commissioning/verification procedures to the contractor administered by this Section of the technical specification. It lastly provides limited assistance to the contractor administered by this Section of the technical specification in its commissioning/verification work.
1. The General Contractor of this project shall directly hire the Control System Integrator in a contract separate from the contract procuring the controls contractor administered by this Section of the technical specifications.
 2. The contractor administered by this Section of the technical specifications shall coordinate all work with the Control System Integrator. The contractor administered by this Section of the technical specifications shall integrate the ASHRAE Standard 135, BACnet/IP control network(s) with the Control System Integrator's area control through an Ethernet connection provided by the Control System Integrator.
 3. The contractor administered by this Section of the technical specifications shall provide a peer-to-peer networked, stand-alone, distributed control system. This direct digital control (DDC) system shall include one portable operator terminal - laptop, one digital display unit, microprocessor-based controllers, instrumentation, end control devices, wiring, piping, software, and related systems. This contractor is responsible for all device mounting and wiring.
 4. Responsibility Table:

Item/Task	Section 23 09 23 contactor	Control system integrator	VA
ECC expansion		X	
ECC programming		X	
Devices, controllers, control panels and equipment	X		

Point addressing: all hardware and software points including setpoint, calculated point, data point(analog/ binary), and reset schedule point	X		
Point mapping		X	
Network Programming	X		
ECC Graphics		X	
Controller programming and sequences	X		
Integrity of LAN communications	X		
Electrical wiring	X		
Operator system training		X	
LAN connections to devices	X		
LAN connections to ECC		X	
IP addresses			X
Overall system verification		X	
Controller and LAN system verification	X		

G. Unitary standalone systems including Unit Heaters, Cabinet Unit Heaters, Fan Coil Units, Base Board Heaters, thermal comfort ventilation fans, and similar units for control of room environment conditions may be equipped with integral controls furnished and installed by the equipment manufacturer or field mounted. Refer to equipment specifications and as indicated in project documents. Application of standalone unitary controls is limited to at least those systems wherein remote monitoring, alarm and start-up are not necessary. Examples of such systems include:

1. Light-switch-operated toilet exhaust
2. Vestibule heater
3. Exterior stair heater
4. Attic heating and ventilation
5. Mechanical or electrical room heating and ventilation.

H. The direct-digital control system shall start and stop equipment, move (position) damper actuators and valve actuators, and vary speed of equipment to execute the mission of the control system. Use electricity as the motive force for all damper and valve actuators, unless use of pneumatics as motive force is specifically granted by the VA.

1.2 RELATED WORK

- A. Section 21 05 11, Common Work Results for Fire Suppression.
- B. Section 21 10 00, Water-Based Fire-Suppression Systems.
- C. Section 22 11 23, Domestic Water Pumps.
- D. Section 23 21 13, Hydronic Piping.
- E. Section 23 31 00, HVAC Ducts and Casings.
- F. Section 23 36 00, Air Terminal Units.
- G. Section 23 73 00, Outdoor Central-Station Air-Handling Units.
- H. Section 23 81 00, Decentralized Unitary HVAC Equipment.
- I. Section 25 10 10, Advanced Utility Metering System.

- J. Section 26 05 11, Requirements for Electrical Installations.
- K. Section 26 05 21, Low-Voltage Electrical Power Conductors and Cables (600 Volts and Below).
- L. Section 26 05 26, Grounding and Bonding for Electrical Systems.
- M. Section 26 05 33, Raceway and Boxes for Electrical Systems.
- N. Section 26 09 23, Lighting Controls.
- O. Section 26 22 21, Specialty Transformers.
- P. Section 26 27 26, Wiring Devices.
- Q. Section 26 29 11, Motor Starters.
- R. Section 26 32 13, Engine Generators.
- S. Section 27 15 00, Communications Horizontal Cabling.
- T. Section 28 31 00, Fire Detection and Alarm.

1.3 DEFINITION

- A. Algorithm: A logical procedure for solving a recurrent mathematical problem; a prescribed set of well-defined rules or processes for the solution of a problem in a finite number of steps.
- B. Analog: A continuously varying signal value (e.g., temperature, current, velocity etc).
- C. BACnet: A Data Communication Protocol for Building Automation and Control Networks , ANSI/ASHRAE Standard 135. This communications protocol allows diverse building automation devices to communicate data over and services over a network.
- D. BACnet/IP: Annex J of Standard 135. It defines and allows for using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP sub-networks that share the same BACnet network number.
- E. BACnet Internetwork: Two or more BACnet networks connected with routers. The two networks may sue different LAN technologies.
- F. BACnet Network: One or more BACnet segments that have the same network address and are interconnected by bridges at the physical and data link layers.
- G. BACnet Segment: One or more physical segments of BACnet devices on a BACnet network, connected at the physical layer by repeaters.
- H. BACnet Broadcast Management Device (BBMD): A communications device which broadcasts BACnet messages to all BACnet/IP devices and other BBMDs connected to the same BACnet/IP network.
- I. BACnet Interoperability Building Blocks (BIBBs): BACnet Interoperability Building Blocks (BIBBs) are collections of one or more BACnet services. These are prescribed in terms of an "A" and a "B" device. Both of these devices are nodes on a BACnet internetwork.
- J. BACnet Testing Laboratories (BTL). The organization responsible for testing products for compliance with the BACnet standard, operated under the direction of BACnet International.
- K. Baud: It is a signal change in a communication link. One signal change

can represent one or more bits of information depending on type of transmission scheme. Simple peripheral communication is normally one bit per Baud. (e.g., Baud rate = 78,000 Baud/sec is 78,000 bits/sec, if one signal change = 1 bit).

- L. Binary: A two-state system where a high signal level represents an "ON" condition and an "OFF" condition is represented by a low signal level.
- M. BMP or bmp: Suffix, computerized image file, used after the period in a DOS-based computer file to show that the file is an image stored as a series of pixels.
- N. Bus Topology: A network topology that physically interconnects workstations and network devices in parallel on a network segment.
- O. Control Unit (CU): Generic term for any controlling unit, stand-alone, microprocessor based, digital controller residing on secondary LAN or Primary LAN, used for local controls or global controls
- P. Deadband: A temperature range over which no heating or cooling is supplied, i.e., 22-25 degrees C (72-78 degrees F), as opposed to a single point change over or overlap).
- Q. Device: a control system component that contains a BACnet Device Object and uses BACnet to communicate with other devices.
- R. Device Object: Every BACnet device requires one Device Object, whose properties represent the network visible properties of that device. Every Device Object requires a unique Object Identifier number on the BACnet internetwork. This number is often referred to as the device instance.
- S. Device Profile: A specific group of services describing BACnet capabilities of a device, as defined in ASHRAE Standard 135-2008, Annex L. Standard device profiles include BACnet Operator Workstations (B-OWS), BACnet Building Controllers (B-BC), BACnet Advanced Application Controllers (B-AAC), BACnet Application Specific Controllers (B-ASC), BACnet Smart Actuator (B-SA), and BACnet Smart Sensor (B-SS). Each device used in new construction is required to have a PICS statement listing which service and BIBBs are supported by the device.
- T. Diagnostic Program: A software test program, which is used to detect and report system or peripheral malfunctions and failures. Generally, this system is performed at the initial startup of the system.
- U. Direct Digital Control (DDC): Microprocessor based control including Analog/Digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices in order to achieve a set of predefined conditions.
- V. Distributed Control System: A system in which the processing of system data is decentralized and control decisions can and are made at the subsystem level. System operational programs and information are provided to the remote subsystems and status is reported back to the Engineering Control Center. Upon the loss of communication with the Engineering Control center, the subsystems shall be capable of operating in a stand-alone mode using the last best available data.
- W. Download: The electronic transfer of programs and data files from a central computer or operation workstation with secondary memory devices

- to remote computers in a network (distributed) system.
- X. DXF: An AutoCAD 2-D graphics file format. Many CAD systems import and export the DXF format for graphics interchange.
 - Y. Electrical Control: A control circuit that operates on line or low voltage and uses a mechanical means, such as a temperature sensitive bimetal or bellows, to perform control functions, such as actuating a switch or positioning a potentiometer.
 - Z. Electronic Control: A control circuit that operates on low voltage and uses a solid-state components to amplify input signals and perform control functions, such as operating a relay or providing an output signal to position an actuator.
 - AA. Engineering Control Center (ECC): The centralized control point for the intelligent control network. The ECC comprises of personal computer and connected devices to form a single workstation.
 - BB. Ethernet: A trademark for a system for exchanging messages between computers on a local area network using coaxial, fiber optic, or twisted-pair cables.
 - CC. Firmware: Firmware is software programmed into read only memory (ROM) chips. Software may not be changed without physically altering the chip.
 - DD. Gateway: Communication hardware connecting two or more different protocols. It translates one protocol into equivalent concepts for the other protocol. In BACnet applications, a gateway has BACnet on one side and non-BACnet (usually proprietary) protocols on the other side.
 - EE. GIF: Abbreviation of Graphic interchange format.
 - FF. Graphic Program (GP): Program used to produce images of air handler systems, fans, chillers, pumps, and building spaces. These images can be animated and/or color-coded to indicate operation of the equipment.
 - GG. Graphic Sequence of Operation: It is a graphical representation of the sequence of operation, showing all inputs and output logical blocks.
 - HH. I/O Unit: The section of a digital control system through which information is received and transmitted. I/O refers to analog input (AI, digital input (DI), analog output (AO) and digital output (DO). Analog signals are continuous and represent temperature, pressure, flow rate etc, whereas digital signals convert electronic signals to digital pulses (values), represent motor status, filter status, on-off equipment etc.
 - II. I/P: a method for conveying and routing packets of information over LAN paths. User Datagram Protocol (UDP) conveys information to "sockets" without confirmation of receipt. Transmission Control Protocol (TCP) establishes "sessions", which have end-to-end confirmation and guaranteed sequence of delivery.
 - JJ. JPEG: A standardized image compression mechanism stands for Joint Photographic Experts Group, the original name of the committee that wrote the standard.
 - KK. Local Area Network (LAN): A communication bus that interconnects operator workstation and digital controllers for peer-to-peer communications, sharing resources and exchanging information.

- LL. Network Repeater: A device that receives data packet from one network and rebroadcasts to another network. No routing information is added to the protocol.
- MM. Native BACnet Device: A device that uses BACnet as its primary method of communication with other BACnet devices without intermediary gateways. A system that uses native BACnet devices at all levels is a native BACnet system.
- NN. Network Number: A site-specific number assigned to each network segment to identify for routing. This network number must be unique throughout the BACnet internetwork.
- OO. Object: The concept of organizing BACnet information into standard components with various associated properties. Examples include analog input objects and binary output objects.
- PP. Object Identifier: An object property used to identify the object, including object type and instance. Object Identifiers must be unique within a device.
- QQ. Object Properties: Attributes of an object. Examples include present value and high limit properties of an analog input object. Properties are defined in ASHRAE 135; some are optional and some are required. Objects are controlled by reading from and writing to object properties.
- RR. Operating system (OS): Software, which controls the execution of computer application programs.
- SS. PCX: File type for an image file. When photographs are scanned onto a personal computer they can be saved as PCX files and viewed or changed by a special application program as Photo Shop.
- TT. Peripheral: Different components that make the control system function as one unit. Peripherals include monitor, printer, and I/O unit.
- UU. Peer-to-Peer: A networking architecture that treats all network stations as equal partners- any device can initiate and respond to communication with other devices.
- VV. PICS: Protocol Implementation Conformance Statement, describing the BACnet capabilities of a device. All BACnet devices have published PICS.
- WW. PID: Proportional, integral, and derivative control, used to control modulating equipment to maintain a setpoint.
- XX. Repeater: A network component that connects two or more physical segments at the physical layer.
- YY. Router: a component that joins together two or more networks using different LAN technologies. Examples include joining a BACnet Ethernet LAN to a BACnet MS/TP LAN.
- ZZ. Sensors: devices measuring state points or flows, which are then transmitted back to the DDC system.
- AAA. Thermostats : devices measuring temperatures, which are used in control of standalone or unitary systems and equipment not attached to the DDC system.

1.4 QUALITY ASSURANCE

A. Criteria:

1. Single Source Responsibility of subcontractor: The Contractor shall obtain hardware and software supplied under this Section and delegate the responsibility to a single source controls installation subcontractor. The controls subcontractor shall be responsible for the complete design, installation, and commissioning of the system. The controls subcontractor shall be in the business of design, installation and service of such building automation control systems similar in size and complexity.
2. Equipment and Materials: Equipment and materials shall be cataloged products of manufacturers regularly engaged in production and installation of HVAC control systems. Products shall be manufacturer's latest standard design and have been tested and proven in actual use.
3. The controls subcontractor shall provide a list of no less than five similar projects which have building control systems as specified in this Section. These projects must be on-line and functional such that the Department of Veterans Affairs (VA) representative would observe the control systems in full operation.
4. The controls subcontractor shall have in-place facility within 50 miles with technical staff, spare parts inventory for the next five (5) years, and necessary test and diagnostic equipment to support the control systems.
5. The controls subcontractor shall have minimum of three years experience in design and installation of building automation systems similar in performance to those specified in this Section. Provide evidence of experience by submitting resumes of the project manager, the local branch manager, project engineer, the application engineering staff, and the electronic technicians who would be involved with the supervision, the engineering, and the installation of the control systems. Training and experience of these personnel shall not be less than three years. Failure to disclose this information will be a ground for disqualification of the supplier.
6. Provide a competent and experienced Project Manager employed by the Controls Contractor. The Project Manager shall be supported as necessary by other Contractor employees in order to provide professional engineering, technical and management service for the work. The Project Manager shall attend scheduled Project Meetings as required and shall be empowered to make technical, scheduling and related decisions on behalf of the Controls Contractor.

B. Codes and Standards:

1. All work shall conform to the applicable Codes and Standards.
2. Electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference, and be so labeled.

1.5 PERFORMANCE

A. The system shall conform to the following:

1. Graphic Display: The system shall display up to four (4) graphics on a single screen with a minimum of twenty (20) dynamic points per graphic. All current data shall be displayed within ten (10) seconds of the request.
2. Graphic Refresh: The system shall update all dynamic points with

current data within eight (8) seconds. Data refresh shall be automatic, without operator intervention.

3. Object Command: The maximum time between the command of a binary object by the operator and the reaction by the device shall be two(2) seconds. Analog objects shall start to adjust within two (2) seconds.
4. Object Scan: All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or work-station will be current, within the prior six (6) seconds.
5. Alarm Response Time: The maximum time from when an object goes into alarm to when it is annunciated at the workstation shall not exceed (10) seconds.
6. Program Execution Frequency: Custom and standard applications shall be capable of running as often as once every (5) seconds. The Contractor shall be responsible for selecting execution times consistent with the mechanical process under control.
7. Multiple Alarm Annunciations: All workstations on the network shall receive alarms within five (5) seconds of each other.
8. Performance: Programmable Controllers shall be able to execute DDC PID control loops at a selectable frequency from at least once every one (1) second. The controller shall scan and update the process value and output generated by this calculation at this same frequency.
9. Reporting Accuracy: Listed below are minimum acceptable reporting end-to-end accuracies for all values reported by the specified system:

Measured Variable	Reported Accuracy
Space temperature	±0.5°C (±1°F)
Ducted air temperature	±0.5°C [±1°F]
Outdoor air temperature	±1.0°C [±2°F]
Dew Point	±1.5°C [±3°F]
Water temperature	±0.5°C [±1°F]
Relative humidity	±2% RH
Water flow	±1% of reading
Air flow (terminal)	±10% of reading
Air flow (measuring stations)	±5% of reading
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO ₂)	±50 ppm
Air pressure (ducts)	±25 Pa [±0.1"w.c.]
Air pressure (space)	±0.3 Pa [±0.001"w.c.]
Water pressure	±2% of full scale *Note 1
Electrical Power	±0.5% of reading

Note 1: for both absolute and differential pressure

10. Control stability and accuracy: Control sequences shall maintain measured variable at setpoint within the following tolerances:

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	± 50 Pa (± 0.2 in. w.g.)	0-1.5 kPa (0-6 in. w.g.)
Air Pressure	± 3 Pa (± 0.01 in. w.g.)	-25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	$\pm 10\%$ of full scale	
Space Temperature	$\pm 1.0^{\circ}\text{C}$ ($\pm 2.0^{\circ}\text{F}$)	
Duct Temperature	$\pm 1.5^{\circ}\text{C}$ ($\pm 3^{\circ}\text{F}$)	
Humidity	$\pm 5\%$ RH	
Fluid Pressure	± 10 kPa (± 1.5 psi)	0-1 MPa (1-150 psi)
Fluid Pressure	± 250 Pa (± 1.0 in. w.g.)	0-12.5 kPa (0-50 in. w.g.) differential

11. Extent of direct digital control: control design shall allow for at least the points indicated on the points lists on the drawings.

1.6 WARRANTY

- A. Labor and materials for control systems shall be warranted for a period as specified under Warranty in FAR clause 52.246-21.
- B. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no cost or reduction in service to the owner. The system includes all computer equipment, transmission equipment, and all sensors and control devices.
- C. Controls and Instrumentation subcontractor shall be responsible for temporary operations and maintenance of the control systems during the construction period until final commissioning, training of facility operators and acceptance of the project by VA.

1.7 SUBMITTALS

- A. Submit shop drawings in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.
- B. Manufacturer's literature and data for all components including the following:
 - 1. A wiring diagram for each type of input device and output device including DDC controllers, modems, repeaters, etc. Diagram shall show how the device is wired and powered, showing typical connections at the digital controllers and each power supply, as well as the device itself. Show for all field connected devices, including but not limited to, control relays, motor starters, electric or electronic actuators, and temperature pressure, flow and humidity sensors and transmitters.
 - 2. A diagram of each terminal strip, including digital controller terminal strips, terminal strip location, termination numbers and the associated point names.
 - 3. Control dampers and control valves schedule, including the size and pressure drop.
 - 4. Catalog cut sheets of all equipment used. This includes, but is not limited to software (by manufacturer and by third parties), DDC

controllers, panels, peripherals, airflow measuring stations and associated components, and auxiliary control devices such as sensors, actuators, and control dampers. When manufacturer's cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted. Each submitted piece of literature and drawings should clearly reference the specification and/or drawings that it supposed to represent.

5. Sequence of operations for each HVAC system and the associated control diagrams. Equipment and control labels shall correspond to those shown on the drawings.
 6. Color prints of proposed graphics with a list of points for display.
 7. Furnish a BACnet Protocol Implementation Conformance Statement (PICS) for each BACnet-compliant device.
 8. Schematic wiring diagrams for all control, communication and power wiring. Provide a schematic drawing of the central system installation. Label all cables and ports with computer manufacturers' model numbers and functions. Show all interface wiring to the control system.
 9. An instrumentation list for each controlled system. Each element of the controlled system shall be listed in table format. The table shall show element name, type of device, manufacturer, model number, and product data sheet number.
 10. Riser diagrams of wiring between central control unit and all control panels.
 11. Scaled plan drawings showing routing of LAN and locations of control panels, controllers, routers, gateways, ECC, and larger controlled devices.
 12. Construction details for all installed conduit, cabling, raceway, cabinets, and similar. Construction details of all penetrations and their protection.
 13. Quantities of submitted items may be reviewed but are the responsibility of the contractor administered by this Section of the technical specifications.
- C. Product Certificates: Compliance with Article, QUALITY ASSURANCE.
- D. Licenses: Provide licenses for all software residing on and used by the Controls Systems and transfer these licenses to the Owner prior to completion.
- E. As Built Control Drawings:
1. Furnish three (3) copies of as-built drawings for each control system. The documents shall be submitted for approval prior to final completion.
 2. Furnish one (1) stick set of applicable control system prints for each mechanical system for wall mounting. The documents shall be submitted for approval prior to final completion.
 3. Furnish one (1) CD-ROM in CAD DWG and/or .DXF format for the drawings noted in subparagraphs above.
- F. Operation and Maintenance (O/M) Manuals):
1. Submit in accordance with Article, INSTRUCTIONS, in Specification Section 01 00 00, GENERAL REQUIREMENTS.
 2. Include the following documentation:
 - a. General description and specifications for all components, including logging on/off, alarm handling, producing trend

- reports, overriding computer control, and changing set points and other variables.
- b. Detailed illustrations of all the control systems specified for ease of maintenance and repair/replacement procedures, and complete calibration procedures.
 - c. One copy of the final version of all software provided including operating systems, programming language, operator workstation software, and graphics software.
 - d. Complete troubleshooting procedures and guidelines for all systems.
 - e. Complete operating instructions for all systems.
 - f. Recommended preventive maintenance procedures for all system components including a schedule of tasks for inspection, cleaning and calibration. Provide a list of recommended spare parts needed to minimize downtime.
 - g. Training Manuals: Submit the course outline and training material to the Owner for approval three (3) weeks prior to the training to VA facility personnel. These persons will be responsible for maintaining and the operation of the control systems, including programming. The Owner reserves the right to modify any or all of the course outline and training material.
 - h. Licenses, guaranty, and other pertaining documents for all equipment and systems.

G. Submit Performance Report to RE/COTR prior to final inspection.

1.8 INSTRUCTIONS

- A. Instructions to VA operations personnel: Perform in accordance with Article, INSTRUCTIONS, in Specification Section 01 00 00, GENERAL REQUIREMENTS, and as noted below. Contractor shall also video tape instruction sessions noted below.
1. First Phase: Formal instructions to the VA facilities personnel for a total of 16 hours, given in multiple training sessions (each no longer than four hours in length), conducted sometime between the completed installation and prior to the performance test period of the control system, at a time mutually agreeable to the Contractor and the VA.
 2. Second Phase: This phase of training shall comprise of on the job training during start-up, checkout period, and performance test period. VA facilities personnel will work with the Contractor's installation and test personnel on a daily basis during start-up and checkout period. During the performance test period, controls subcontractor will provide 16 hours of instructions, given in multiple training sessions (each no longer than four hours in length), to the VA facilities personnel.
 3. The O/M Manuals shall contain approved submittals as outlined in Article 1.7, SUBMITTALS. The Controls subcontractor will review the manual contents with VA facilities personnel during second phase of training.
 4. Training shall be given by direct employees of the controls system subcontractor.

1.9 PROJECT CONDITIONS (ENVIRONMENTAL CONDITIONS OF OPERATION)

- A. The ECC and peripheral devices and system support equipment shall be designed to operate in ambient condition of 20 to 35°C (65 to 90°F) at a relative humidity of 20 to 80% non-condensing.

- B. The CUs used outdoors shall be mounted in NEMA 4 waterproof enclosures, and shall be rated for operation at -40 to 65°C (-40 to 150°F).
- C. All electronic equipment shall operate properly with power fluctuations of plus 10 percent to minus 15 percent of nominal supply voltage.
- D. Sensors and controlling devices shall be designed to operate in the environment, which they are sensing or controlling.

1.10 APPLICABLE PUBLICATIONS

- A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.
- B. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):
Standard 135-10.....BACNET Building Automation and Control Networks
- C. American Society of Mechanical Engineers (ASME):
B16.18-01.....Cast Copper Alloy Solder Joint Pressure Fittings.
B16.22-01.....Wrought Copper and Copper Alloy Solder Joint Pressure Fittings.
- D. American Society of Testing Materials (ASTM):
B32-08Standard Specification for Solder Metal
B88-09.....Standard Specifications for Seamless Copper Water Tube
B88M-09.....Standard Specification for Seamless Copper Water Tube (Metric)
B280-08.....Standard Specification for Seamless Copper Tube for Air-Conditioning and Refrigeration Field Service
D2737-03.....Standard Specification for Polyethylene (PE) Plastic Tubing
- E. Federal Communication Commission (FCC):
Rules and Regulations Title 47 Chapter 1-2001 Part 15: Radio Frequency Devices.
- F. Institute of Electrical and Electronic Engineers (IEEE):
802.3-11.....Information Technology-Telecommunications and Information Exchange between Systems-Local and Metropolitan Area Networks- Specific Requirements-Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access method and Physical Layer Specifications

- G. National Fire Protection Association (NFPA):
 70-11National Electric Code
 90A-12Standard for Installation of Air-Conditioning
 and Ventilation Systems
- H. Underwriter Laboratories Inc (UL):
 94-10Tests for Flammability of Plastic Materials for
 Parts and Devices and Appliances
 294-10Access Control System Units
 486A/486B-10Wire Connectors
 555S-11Standard for Smoke Dampers
 916-10Energy Management Equipment
 1076-10Proprietary Burglar Alarm Units and Systems

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Use new products that the manufacturer is currently manufacturing and that have been installed in a minimum of 25 installations. Spare parts shall be available for at least five years after completion of this contract.

2.2 CONTROLS SYSTEM ARCHITECTURE

- A. General:
1. The Controls Systems shall consist of multiple Nodes and associated equipment connected by industry standard digital and communication network arrangements.
 2. The ECC, building controllers and principal communications network equipment shall be standard products of recognized major manufacturers available through normal PC and computer vendor channels - not "Clones" assembled by a third-party subcontractor.
 3. The networks shall, at minimum, comprise, as necessary, the following:
 - a. A fixed ECC and a portable operator's terminal.
 - b. Network computer processing, data storage and BACnet-compliant communication equipment including Servers and digital data processors.
 - c. BACnet-compliant routers, bridges, switches, hubs, modems, gateways, interfaces and similar communication equipment.
 - d. Active processing BACnet-compliant building controllers connected to other BACNet-compliant controllers together with their power supplies and associated equipment.
 - e. Addressable elements, sensors, transducers and end devices.
 - f. Third-party equipment interfaces and gateways as described and required by the Contract Documents.
 - g. Other components required for a complete and working Control Systems as specified.
- B. The Specifications for the individual elements and component subsystems shall be minimum requirements and shall be augmented as necessary by the Contractor to achieve both compliance with all applicable codes, standards and to meet all requirements of the Contract Documents.

C. Network Architecture

1. The Controls communication network shall utilize BACnet communications protocol operating over a standard Ethernet LAN and operate at a minimum speed of 100 Mb/sec.
2. The networks shall utilize only copper and optical fiber communication media as appropriate and shall comply with applicable codes, ordinances and regulations.
3. All necessary telephone lines, ISDN lines and internet Service Provider services and connections will be provided by the VA.

D. Third Party Interfaces:

1. The contractor administered by this Section of the technical specifications shall include necessary hardware, equipment, software and programming to allow data communications between the controls systems and building systems supplied by other trades.
2. Other manufacturers and contractors supplying other associated systems and equipment shall provide their necessary hardware, software and start-up at their cost and shall cooperate fully with the contractor administered by this Section of the technical specifications in a timely manner and at their cost to ensure complete functional integration.

E. Servers:

1. Provide data storage server(s) to archive historical data including trends, alarm and event histories and transaction logs.
2. Equip these server(s) with the same software tool set that is located in the BACnet building controllers for system configuration and custom logic definition and color graphic configuration.
3. Access to all information on the data storage server(s) shall be through the same browser functionality used to access individual nodes. When logged onto a server the operator will be able to also interact with any other controller on the control system as required for the functional operation of the controls systems. The contractor administered by this Section of the technical specifications shall provide all necessary digital processor programmable data storage server(s).
4. These server(s) shall be utilized for controls systems application configuration, for archiving, reporting and trending of data, for operator transaction archiving and reporting, for network information management, for alarm annunciation, for operator interface tasks, for controls application management and similar. These server(s) shall utilize IT industry standard data base platforms which utilize a database declarative language designed for managing data in relational database management systems (RDBMS) such as SQL.

2.3 COMMUNICATION

- A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135-2008, BACnet.
1. The Data link / physical layer protocol (for communication) acceptable to the VA throughout its facilities is Ethernet (ISO 8802-3) and BACnet/IP.
- B. Each controller shall have a communication port for connection to an operator interface.

- C. Project drawings indicate remote buildings or sites to be connected by a nominal 56,000 baud modem over voice-grade telephone lines. In each remote location a modem and field device connection shall allow communication with each controller on the internetwork as specified in Paragraph D.
- D. Internetwork operator interface and value passing shall be transparent to internetwork architecture.
 - 1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, reports, system software, and custom programs shall be viewable and editable from each internetwork controller.
 - 2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute specified control system operation. An authorized operator shall be able to edit cross-controller links by typing a standard object address.
- E. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring. Expansion shall not require operator interface hardware additions or software revisions.
- F. ECCs and Controllers with real-time clocks shall use the BACnet 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.

2.4 ENGINEERING CONTROL CENTER (ECC)

- A. The ECC shall reside on a high-speed network with controllers as shown on system drawings. The ECC and each standard browser connected to server shall be able to access all system information.
- B. ECC and controllers shall communicate using BACnet protocol. ECC and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ASHRAE/ANSI 135-2008, BACnet Annex J.
- C. Hardware: ECC shall conform to the BACnet Advanced Workstation (B-AWS) Profile and shall be BTL-Listed as a B-AWS device.
 - 1. ECC shall be commercial standard with supporting 32- or 64-bit hardware (as required by the direct-digital control system software) and software enterprise server. Internet Explorer v6.0 SP1 or higher, Windows Script Hosting version 5.6 or higher, Windows Message Queuing, Windows Internet Information Services (IIS) v5.0 or higher, minimum 2.8 GHz processor, minimum 4GB DDR3 SDRAM (minimum 1333 Mhz) memory, 512 MB video card, and 16 speed high density DVD-RW+/- optical drive.
 - a. The hard drive shall be at the minimum 1 TB 7200 rpm SATA hard drive with 16 MB cache, and shall have sufficient memory to store:
 - 1) All required operator workstation software
 - 2) A DDC 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.

- b. Real-time clock:
 - 1) Accuracy: Plus or minus 1 minute per month.
 - 2) Time Keeping Format: 24-hour time format including seconds, minutes, hours, date, day, and month; automatic reset by software.
 - 3) Clock shall function for one year without power.
 - 4) Provide automatic time correction once every 24 hours by synchronizing clock with the Time Service Department of the U.S. Naval Observatory.
- c. Serial ports: Four USB ports and two RS-232-F serial ports for general use, with additional ports as required. Data transmission rates shall be selectable under program control.
- d. Parallel port: Enhanced.
- e. Sound card: For playback and recording of digital WAV sound files associated with audible warning and alarm functions.
- f. Color monitor: PC compatible, not less than 22 inches, LCD type, with a minimum resolution of 1280 by 1024 pixels, non-interlaced, and a maximum dot pitch of 0.28 mm.
- g. Keyboard: Minimum of 64 characters, standard ASCII character set based on ANSI INCITS 154.
- h. Mouse: Standard, compatible with installed software.
- i. Removable disk storage: Include the following, each with appropriate controller:
 - 1) Minimum 1 TB removable hard disk, maximum average access time of 10 ms.
- j. Network interface card (NIC): integrated 10-100-1000 Base-TX Ethernet NIC with an RJ45 connector or a 100Base-FX Ethernet NIC with an SC/ST connector.
- 2. Cable modem: 42.88 MBit/s, DOCSIS 2.0 Certified, also backwards compatible with DOCSIS 1.1/1.0 standards. Provide Ethernet or USB connectivity.
- 3. Optical modem: full duplex link, for use on 10 GBase-R single-mode and multi-mode fiber with a XENPAK module.
- 4. Auto-dial modem: 56,600 bps, full duplex for asynchronous communications. With error detection, auto answer/autodial, and call-in-progress detection. Modem shall comply with requirements in ITU-T v.34, ITU-T v.42, ITU-T v.42 Appendix VI for error correction, and ITU-T v.42 BIS for data compression standards; and shall be suitable for operating on unconditioned voice-grade telephone lines complying with 47 CFR 68.
- 5. Audible Alarm: Manufacturer's standard.
- 6. Printers:
 - a. Provide a dedicated, minimum resolution 600 dpi, color laser printer, connected to the ECC through a USB interface.
 - 1) If a network printer is used instead of this dedicated printer, it shall have a 100Base-T interface with an RJ45 connection and shall have a firmware print spooler compatible with the Operating System print spooler.
 - 2) RAM: 512 MB, minimum.
 - 3) Printing Speed: Minimum twenty six pages per minute (color); minimum 30 pages per minute (black/white).
 - 4) Paper Handling: Automatic sheet feeder with 250-sheet x 8.5 inch x 11 inch paper cassette and with automatic feed.
 - b. Provide a dedicated black/white tractor-feed dot matrix printer for status/alarm message printing, minimum 10 characters per inch, minimum 160 characters per second, connected to the ECC through a USB interface.

- 1) Paper: One box of 2000 sheets of 8-1/2x11 multi-fold type printer paper.
7. RS-232 ASCII Interface
 - a. ASCII interface shall allow RS-232 connections to be made between a meter or circuit monitor operating as the host PC and any equipment that will accept RS-232 ASCII command strings, such as local display panels, dial-up modems, and alarm transmitters.
 - b. Pager System Interface: Alarms shall be able to activate a pager system with customized message for each input alarm.
 - c. Alarm System Interface: RS-232 output shall be capable of transmitting alarms from other monitoring and alarm systems to workstation software.
 - d. RS-232 output shall be capable of connection to a pager interface that can be used to call a paging system or service and send a signal to a portable pager. System shall allow an individual alphanumeric message per alarm input to be sent to paging system. This interface shall support both numeric and alphanumeric pagers.
 - e. Cables: provide Plenum-Type, RS-232 Cable: Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors, plastic insulation, and individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage; plastic jacket. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned copper drain wire.
 - 1) NFPA 70, Type CMP.
 - 2) Flame Resistance: NFPA 262, Flame Test.
8. Self-contained uninterruptible power supply (UPS):
 - a. Size: Provide a minimum of six hours of operation of ECC equipment, including two hours of alarm printer operation.
 - b. Batteries: Sealed, valve regulated, recombinant, lead calcium.
 - c. Accessories:
 - 1) Transient voltage suppression.
 - 2) Input-harmonics reduction.
 - 3) Rectifier/charger.
 - 4) Battery disconnect device.
 - 5) Static bypass transfer switch.
 - 6) Internal maintenance bypass/isolation switch.
 - 7) External maintenance bypass/isolation switch.
 - 8) Output isolation transformer.
 - 9) Remote UPS monitoring.
 - 10) Battery monitoring.
 - 11) Remote battery monitoring.
- D. ECC Software:
 1. Provide for automatic system database save and restore on the ECC's hard disk a copy of the current database of each Controller. This database shall be updated whenever a change is made in any system panel. In the event of a database loss in a building management panel, the ECC shall automatically restore the database for that panel. This capability may be disabled by the operator.
 2. Provide for manual database save and restore. An operator with proper 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.
 3. Provide a method of configuring the system. This shall allow for

- future system changes or additions by users with proper clearance.
4. Operating System. Furnish a concurrent multi-tasking operating system. The operating system also shall support the use of other common software applications. Acceptable operating systems are Windows XP, Windows System 7, Linux, and UNIX.
 5. System Graphics. The operator workstation software shall be graphically oriented. The system shall allow display of up to 10 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 on-line. 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.
 6. 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.
 7. 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.
 8. The Controls Systems Operator Interfaces shall be user friendly, readily understood and shall make maximum use of colors, graphics, icons, embedded images, animation, text based information and data visualization techniques to enhance and simplify the use and understanding of the displays by authorized users at the ECC. The operating system shall be Windows XP or better, and shall support the third party software.
 9. Provide graphical user software, which shall minimize the use of keyboard through the use of the mouse and "point and click" approach to menu selection.
 10. The software shall provide a multi-tasking type environment that will allow the user to run several applications simultaneously. The mouse or Alt-Tab keys shall be used to quickly select and switch between multiple applications. The operator shall be able automatically export data to and work in Microsoft Word, Excel, and other Windows based software programs, while concurrently on-line system alarms and monitoring information.
 11. On-Line Help. Provide a context-sensitive, on-line help system to assist the operator in operating and editing the system. On-line 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.
 12. User access shall be protected by a flexible and Owner re-definable software-based password access protection. Password protection shall be multi-level and partition able to accommodate the varied

- access requirements of the different user groups to which individual users may be assigned. Provide the means to define unique access privileges for each individual authorized user. Provide the means to on-line manage password access control under the control of a project specific Master Password. Provide an audit trail of all user activity on the Controls Systems including all actions and changes.
13. The system shall be completely field-programmable from the common operator's keyboard thus allowing hard disk storage of all data automatically. All programs for the CUs shall be able to be downloaded from the hard disk. The software shall provide the following functionality as a minimum:
 - a. Point database editing, storage and downloading of controller databases.
 - b. Scheduling and override of building environmental control systems.
 - c. Collection and analysis of historical data.
 - d. Alarm reporting, routing, messaging, and acknowledgement.
 - e. Definition and construction of dynamic color graphic displays.
 - f. Real-time graphical viewing and control of environment.
 - g. Scheduling trend reports.
 - h. Program editing.
 - i. Operating activity log and system security.
 - j. Transfer data to third party software.
 14. Provide functionality such that using the least amount of steps to initiate the desired event may perform any of the following simultaneously:
 - a. Dynamic color graphics and graphic control.
 - b. Alarm management.
 - c. Event scheduling.
 - d. Dynamic trend definition and presentation.
 - e. Program and database editing.
 - f. Each operator shall be required to log on to the system with a user name and password to view, edit or delete the data. System security shall be selectable for each operator, and the password shall be able to restrict the operator's access for viewing and changing the system programs. Each operator shall automatically be logged off the system if no keyboard or mouse activity is detected for a selected time.
 15. Graphic Displays:
 - a. The workstation shall allow the operator to access various system schematics and floor plans via a graphical penetration scheme, menu selection, or text based commands. Graphic software shall permit the importing of AutoCAD or scanned pictures in the industry standard format (such as PCX, BMP, GIF, and JPEG) for use in the system.
 - b. System Graphics shall be project specific and schematically correct for each system. (ie: coils, fans, dampers located per equipment supplied with project.) Standard system graphics that do not match equipment or system configurations are not acceptable. Operator shall have capability to manually operate the entire system from each graphic screen at the ECC. Each system graphic shall include a button/tab to a display of the applicable sequence of operation.
 - c. Dynamic temperature values, humidity values, flow rates, and status indication shall be shown in their locations and shall automatically update to represent current conditions without

- operator intervention and without pre-defined screen refresh values.
- d. Color shall be used to indicate status and change in status of the equipment. The state colors shall be user definable.
 - e. A clipart library of HVAC equipment, such as chillers, boilers, air handling units, fans, terminal units, pumps, coils, standard ductwork, piping, valves and laboratory symbols shall be provided in the system. The operator shall have the ability to add custom symbols to the clipart library.
 - f. A dynamic display of the site-specific architecture showing status of the controllers, the ECC and network shall be provided.
 - g. The windowing environment of the workstation shall allow the user to simultaneously view several applications at a time to analyze total building operation or to allow the display of graphic associated with an alarm to be viewed without interrupting work in progress. The graphic system software shall also have the capability to split screen, half portion of the screen with graphical representation and the other half with sequence of operation of the same HVAC system.
16. Trend reports shall be generated on demand or pre-defined schedule and directed to monitor display, printers or disk. As a minimum, the system shall allow the operator to easily obtain the following types of reports:
- a. A general list of all selected points in the network.
 - b. List of all points in the alarm.
 - c. List of all points in the override status.
 - d. List of all disabled points.
 - e. List of all points currently locked out.
 - f. List of user accounts and password access levels.
 - g. List of weekly schedules.
 - h. List of holiday programming.
 - i. List of limits and dead bands.
 - j. Custom reports.
 - k. System diagnostic reports, including, list of digital controllers on the network.
 - l. List of programs.
17. ASHRAE Standard 147 Report: Provide a daily report that shows the operating condition of each chiller as recommended by ASHRAE Standard 147. At a minimum, this report shall include:
- a. Chilled water (or other secondary coolant) inlet and outlet temperature
 - b. Chilled water (or other secondary coolant) flow
 - c. Chilled water (or other secondary coolant) inlet and outlet pressures
 - d. Evaporator refrigerant pressure and temperature
 - e. Condenser refrigerant pressure and liquid temperature
 - f. Condenser water inlet and outlet temperatures
 - g. Condenser water flow
 - h. Refrigerant levels
 - i. Oil pressure and temperature
 - j. Oil level
 - k. Compressor refrigerant discharge temperature
 - l. Compressor refrigerant suction temperature
 - m. Addition of refrigerant
 - n. Addition of oil
 - o. Vibration levels or observation that vibration is not excessive

- p. Motor amperes per phase
 - q. Motor volts per phase
 - r. PPM refrigerant monitor level
 - s. Purge exhaust time or discharge count
 - t. Ambient temperature (dry-bulb and wet-bulb)
 - u. Date and time logged
18. Electrical and Weather Reports:
- a. 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.
 - b. Provide an annual (12-month) summary report showing the monthly electrical consumption and peak demand with time and date stamp for each meter.
 - c. Provide an annual (12-month) summary report showing the monthly heating and cooling consumption with time and date stamp for each meter.
 - d. Provide an annual (12-month) summary report showing the monthly water consumption with time and date stamp for each meter. Refer to plumbing drawings for location and quantity.
 - e. 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.
19. Scheduling and Override:
- a. Provide override access through menu selection from the graphical interface and through a function key.
 - b. Provide a calendar type format for time-of-day scheduling and overrides of building control systems. Schedules reside in the ECC. The digital controllers shall ensure equipment time scheduling when the ECC is off-line. The ECC shall not be required to execute time scheduling. Provide the following spreadsheet graphics as a minimum:
 - 1) Weekly schedules.
 - 2) Zone schedules, minimum of 100 zones.
 - 3) Scheduling up to 365 days in advance.
 - 4) Scheduled reports to print at workstation.
20. Collection and Analysis of Historical Data:
- a. Provide trending capabilities that will allow the operator to monitor and store records of system activity over an extended period of time. Points may be trended automatically on time based intervals or change of value, both of which shall be user definable. The trend interval could be five (5) minutes to 120 hours. Trend data may be stored on hard disk for future diagnostic and reporting. Additionally trend data may be archived to network drives or removable disk media for off-site retrieval.
 - b. Reports may be customized to include individual points or predefined groups of at least six points. Provide additional functionality to allow pre-defined groups of up to 250 trended points to be easily accessible by other industry standard word processing and spreadsheet packages. The reports shall be time and date stamped and shall contain a report title and the name of the facility.
 - c. System shall have the set up to generate spreadsheet reports to

track energy usage and cost based on weekly or monthly interval, equipment run times, equipment efficiency, and/or building environmental conditions.

- d. Provide additional functionality that will allow the operator to view real time trend data on trend graph displays. A minimum of 20 points may be graphed regardless of whether they have been predefined for trending. In addition, the user may pause the graph and take snapshots of the screens to be stored on the workstation disk for future reference and trend analysis. Exact point values may be viewed and the graph may be printed. Operator shall be able to command points directly on the trend plot by double clicking on the point.

21. Alarm Management:

- a. Alarm routing shall allow the operator to send alarm notification to selected printers or operator workstation based on time of day, alarm severity, or point type.
- b. Alarm notification shall be provided via two alarm icons, to distinguish between routine, maintenance type alarms and critical alarms. The critical alarms shall display on the screen at the time of its occurrence, while others shall display by clicking on their icon.
- c. Alarm display shall list the alarms with highest priority at the top of the display. The alarm display shall provide selector buttons for display of the associated point graphic and message in English language. The operator shall be able to sort out the alarms.
- d. Alarm messages shall be customized for each point to display detailed instructions to the operator regarding actions to take in the event of an alarm.
- e. An operator with proper security level access may acknowledge and clear the alarm. All that have not been cleared shall be archived at workstation disk.

22. Remote Communications: The system shall have the ability to dial out in the event of an alarm. Receivers shall include operator workstations, e-mail addresses, and alpha-numeric pagers. The alarm message shall include the name of the calling location, the device that generated the alarm, and the alarm message itself.

23. System Configuration:

- a. Network control strategies shall not be restricted to a single digital controller, but shall be able to include data from all other network devices to allow the development of global control strategies.
- b. Provide automatic backup and restore of all digital controller databases on the workstation hard disk. In addition to all backup data, all databases shall be performed while the workstation is on-line without disturbing other system operations.

2.5 PORTABLE OPERATOR'S TERMINAL (POT)

- A. Provide a portable operator's terminal (POT) that shall be capable of accessing all system data. POT may be connected to any point on the system network or may be connected directly to any controller for programming, setup, and troubleshooting. POT shall communicate using BACnet protocol. POT may be connected to any point on the system network or it may be connected directly to controllers using the BACnet PTP (Point-To-Point) Data Link/ Physical layer protocol. The terminal shall use the Read (Initiate) and Write (Execute) BACnet Services. POT

shall be an IBM-compatible notebook-style PC including all software and hardware required.

- B. Hardware: POT shall conform to the BACnet Advanced Workstation (B-AWS) Profile and shall be BTL-Listed as a B-AWS device.
 - 1. POT shall be commercial standard with supporting 32- or 64-bit hardware (as limited by the direct-digital control system software) and software enterprise server. Internet Explorer v6.0 SP1 or higher, Windows Script Hosting version 5.6 or higher, Windows Message Queuing, Windows Internet Information Services (IIS) v5.0 or higher, minimum 2.8 GHz processor, minimum 500 GB 7200 rpm SATA hard drive with 16 MB cache, minimum 2GB DDR3 SDRAM (minimum 1333 Mhz) memory, 512 MB video card, minimum 16 inch (diagonal) screen, 10-100-1000 Base-TX Ethernet NIC with an RJ45 connector or a 100Base-FX Ethernet NIC with an SC/ST connector, 56,600 bps modem, an ASCII RS-232 interface, and a 16 speed high density DVD-RW+/- optical drive.
- C. Software: POT shall include software equal to the software on the ECC.

2.6 BACNET PROTOCOL ANALYZER

- A. For ease of troubleshooting and maintenance, provide a BACnet protocol analyzer. Provide its associated fittings, cables and appurtenances, for connection to the communications network. The BACnet protocol analyzer shall be able to, at a minimum: capture and store to a file all data traffic on all network levels; measure bandwidth usage; filter out (ignore) selected traffic.

2.7 NETWORK AND DEVICE NAMING CONVENTION

- A. Network Numbers:
 - 1. BACnet network numbers shall be based on a "facility code, network" concept. The "facility code" is the VAMC's or VA campus' assigned numeric value assigned to a specific facility or building. The "network" typically corresponds to a "floor" or other logical configuration within the building. BACnet allows 65535 network numbers per BACnet internet work.
 - 2. The network numbers are thus formed as follows: "Net #" = "FFFNN" where:
 - 1. FFF = Facility code (see below)
 - 2. NN = 00-99 This allows up to 100 networks per facility or building
- B. Device Instances:
 - 1. BACnet allows 4194305 unique device instances per BACnet internet work. Using Agency's unique device instances are formed as follows: "Dev #" = "FFFNNDD" where
 - 1. FFF and N are as above and
 - 2. DD = 00-99, this allows up to 100 devices per network.
 - 2. Note Special cases, where the network architecture of limiting device numbering to DD causes excessive subnet works. The device number can be expanded to DDD and the network number N can become a single digit. In NO case shall the network number N and the device number D exceed 4 digits.
 - 3. Facility code assignments:
 - 4. 000-400 Building/facility number
 - 5. Note that some facilities have a facility code with an alphabetic suffix to denote wings, related structures, etc. The suffix will be

ignored. Network numbers for facility codes above 400 will be assigned in the range 000-399.

C. Device Names:

1. Name the control devices based on facility name, location within a facility, the system or systems that the device monitors and/or controls, or the area served. The intent of the device naming is to be easily recognized. Names can be up to 254 characters in length, without embedded spaces. Provide the shortest descriptive, but unambiguous, name. For example, in building #123 prefix the number with a "B" followed by the building number, if there is only one chilled water pump "CHWP-1", a valid name would be "B123.CHWP.1.STARTSTOP". If there are two pumps designated "CHWP-1", one in a basement mechanical room (Room 0001) and one in a penthouse mechanical room (Room PH01), the names could be "B123.R0001.CHWP.1.STARTSTOP" or "B123.RPH01.CHWP.1.STARTSTOP". In the case of unitary controllers, for example a VAV box controller, a name might be "B123.R101.VAV". These names should be used for the value of the "Object_Name" property of the BACnet Device objects of the controllers involved so that the BACnet name and the EMCS name are the same.

2.8 BACNET DEVICES

- A. All BACnet Devices - controllers, gateways, routers, actuators and sensors shall conform to BACnet Device Profiles and shall be BACnet Testing Laboratories (BTL) -Listed as conforming to those Device Profiles. Protocol Implementation Conformance Statements (PICSs), describing the BACnet capabilities of the Devices shall be published and available of the Devices through links in the BTL website.
 1. BACnet Building Controllers, historically referred to as NACs, shall conform to the BACnet B-BC Device Profile, and shall be BTL-Listed as conforming to the B-BC Device Profile. The Device's PICS shall be submitted.
 2. BACnet Advanced Application Controllers shall conform to the BACnet B-AAC Device Profile, and shall be BTL-Listed as conforming to the B-AAC Device Profile. The Device's PICS shall be submitted.
 3. BACnet Application Specific Controllers shall conform to the BACnet B-ASC Device Profile, and shall be BTL-Listed as conforming to the B-ASC Device Profile. The Device's PICS shall be submitted.
 4. BACnet Smart Actuators shall conform to the BACnet B-SA Device Profile, and shall be BTL-Listed as conforming to the B-SA Device Profile. The Device's PICS shall be submitted.
 5. BACnet Smart Sensors shall conform to the BACnet B-SS Device Profile, and shall be BTL-Listed as conforming to the B-SS Device Profile. The Device's PICS shall be submitted.
 6. BACnet routers and gateways shall conform to the BACnet B-OTH Device Profile, and shall be BTL-Listed as conforming to the B-OTH Device Profile. The Device's PICS shall be submitted.

2.9 CONTROLLERS

- A. General. Provide an adequate number of BTL-Listed B-BC building controllers and an adequate number of BTL-Listed B-AAC advanced application controllers to achieve the performance specified in the Part 1 Article on "System Performance." Each of these controllers shall meet the following requirements.
 1. The controller shall have sufficient memory to support its operating system, database, and programming requirements.

2. The building controller shall share data with the ECC and the other networked building controllers. The advanced application controller shall share data with its building controller and the other networked advanced 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 for central monitoring and alarms.
 4. Controllers that perform scheduling shall have a real-time clock.
 5. The controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall:
 - a. Assume a predetermined failure mode, and
 - b. Generate an alarm notification.
 6. The controller shall communicate with other BACnet devices on the internetwork using the BACnet Read (Execute and Initiate) and Write (Execute and Initiate) Property services.
 7. Communication:
 - a. Each controller shall reside on a BACnet network using the ISO 8802-3 (Ethernet) Data Link/Physical layer protocol for its communications. Each building controller also shall perform BACnet routing if connected to a network of custom application and application specific controllers.
 - b. The controller shall provide a service communication port using BACnet Data Link/Physical layer protocol for connection to a portable operator's terminal.
 8. Keypad. A local keypad and display shall be provided for each controller. The keypad shall be provided for interrogating and editing data. Provide a system security password shall be available to prevent unauthorized use of the keypad and display.
 9. 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.
 10. Memory. The controller shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.
 11. The controller shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Controller 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).
- B. Provide BTL-Listed B-ASC application specific controllers for each piece of equipment for which they are constructed. Application specific controllers shall communicate with other BACnet devices on the internetwork using the BACnet Read (Execute) Property service.
1. Each B-ASC shall be capable of stand-alone operation and shall continue to provide control functions without being connected to the network.
 2. Each B-ASC will contain sufficient I/O capacity to control the target system.
 3. Communication.
 - a. Each controller shall reside on a BACnet network using the ISO 8802-3 (Ethernet) Data Link/Physical layer protocol for its communications. Each building controller also shall perform BACnet routing if connected to a network of custom application and application specific controllers.

- b. Each controller shall have a BACnet Data Link/Physical layer compatible connection for a laptop computer or a portable operator's tool. This connection shall be extended to a space temperature sensor port where shown.
 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 application specific controller shall use nonvolatile memory and maintain all BIOS and programming information in the event of a power loss.
 6. Immunity to power and noise. Controllers 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 5-120 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.
- C. Direct Digital Controller Software:
 1. The software programs specified in this section shall be commercially available, concurrent, multi-tasking operating system and support the use of software application that operates under DOS or Microsoft Windows.
 2. All points shall be identified by up to 30-character point name and 16-character point descriptor. The same names shall be used at the ECC.
 3. All control functions shall execute within the stand-alone control units via DDC algorithms. The VA shall be able to customize control strategies and sequences of operations defining the appropriate control loop algorithms and choosing the optimum loop parameters.
 4. All controllers shall be capable of being programmed to utilize stored default values for assured fail-safe operation of critical processes. Default values shall be invoked upon sensor failure or, if the primary value is normally provided by the central or another CU, or by loss of bus communication. Individual application software packages shall be structured to assume a fail-safe condition upon loss of input sensors. Loss of an input sensor shall result in output of a sensor-failed message at the ECC. Each ACU and RCU shall have capability for local readouts of all functions. The UCUs shall be read remotely.
 5. All DDC control loops shall be able to utilize any of the following control modes:
 - a. Two position (on-off, slow-fast) control.
 - b. Proportional control.
 - c. Proportional plus integral (PI) control.
 - d. Proportional plus integral plus derivative (PID) control. All PID programs shall automatically invoke integral wind up prevention routines whenever the controlled unit is off, under manual control of an automation system or time initiated program.
 - e. Automatic tuning of control loops.
 6. System Security: Operator access shall be secured using individual password and operator's name. Passwords shall restrict the operator to the level of object, applications, and system functions assigned

to him. A minimum of six (6) levels of security for operator access shall be provided.

7. Application Software: The controllers shall provide the following programs as a minimum for the purpose of optimizing energy consumption while maintaining comfortable environment for occupants. All application software shall reside and run in the system digital controllers. Editing of the application shall occur at the ECC or via a portable operator's terminal, when it is necessary, to access directly the programmable unit.
 - a. Power Demand Limiting (PDL): Power demand limiting program shall monitor the building power consumption and limit the consumption of electricity to prevent peak demand charges. PDL shall continuously track the electricity consumption from a pulse input generated at the kilowatt-hour/demand electric meter. PDL shall sample the meter data to continuously forecast the electric demand likely to be used during successive time intervals. If the forecast demand indicates that electricity usage will likely to exceed a user preset maximum allowable level, then PDL shall automatically shed electrical loads. Once the demand load has met, loads that have been shed shall be restored and returned to normal mode. Control system shall be capable of demand limiting by resetting the HVAC system set points to reduce load while maintaining indoor air quality.
 - b. Economizer: An economizer program shall be provided for VAV systems. This program shall control the position of air handler relief, return, and outdoors dampers. If the outdoor air dry bulb temperature falls below changeover set point the energy control center will modulate the dampers to provide 100 percent outdoor air. The operator shall be able to override the economizer cycle and return to minimum outdoor air operation at any time.
 - c. Night Setback/Morning Warm up Control: The system shall provide the ability to automatically adjust set points for this mode of operation.
 - d. Optimum Start/Stop (OSS): Optimum start/stop program shall automatically be coordinated with event scheduling. The OSS program shall start HVAC equipment at the latest possible time that will allow the equipment to achieve the desired zone condition by the time of occupancy, and it shall also shut down HVAC equipment at the earliest possible time before the end of the occupancy period and still maintain desired comfort conditions. The OSS program shall consider both outside weather conditions and inside zone conditions. The program shall automatically assign longer lead times for weekend and holiday shutdowns. The program shall poll all zones served by the associated AHU and shall select the warmest and coolest zones. These shall be used in the start time calculation. It shall be possible to assign occupancy start times on a per air handler unit basis. The program shall meet the local code requirements for minimum outdoor air while the building is occupied. Modification of assigned occupancy start/stop times shall be possible via the ECC.
 - e. Event Scheduling: Provide a comprehensive menu driven program to automatically start and stop designated points or a group of points according to a stored time. This program shall provide the capability to individually command a point or group of points. When points are assigned to one common load group it

shall be possible to assign variable time advances/delays between each successive start or stop within that group. Scheduling shall be calendar based and advance schedules may be defined up to one year in advance. Advance schedule shall override the day-to-day schedule. The operator shall be able to define the following information:

- 1) Time, day.
 - 2) Commands such as on, off, auto.
 - 3) Time delays between successive commands.
 - 4) Manual overriding of each schedule.
 - 5) Allow operator intervention.
- f. 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 ECC based on time and events. An alarm shall be able to start programs, login the event, print and display the messages. The system shall allow the operator to prioritize the alarms to minimize nuisance reporting and to speed operator's response to critical alarms. A minimum of six (6) priority levels of alarms shall be provided for each point.
- g. Remote Communications: The system shall have the ability to dial out in the event of an alarm to the ECC and alpha-numeric pagers. The alarm message shall include the name of the calling location, the device that generated the alarm, and the alarm message itself. The operator shall be able to remotely access and operate the system using dial up communications. Remote access shall allow the operator to function the same as local access.
- h. Maintenance Management (PM): The program shall monitor equipment status and generate maintenance messages based upon the operators defined equipment run time, starts, and/or calendar date limits. A preventative maintenance alarm shall be printed indicating maintenance requirements based on pre-defined run time. Each preventive message shall include point description, limit criteria and preventative maintenance instruction assigned to that limit. A minimum of 480-character PM shall be provided for each component of units such as air handling units.

2.10 SENSORS (AIR AND WATER)

- A. Sensors' measurements shall be read back to the DDC system, and shall be visible by the ECC.
- B. Temperature and Humidity Sensors shall be electronic, vibration and corrosion resistant for wall, immersion, and/or duct mounting. Provide all remote sensors as required for the systems.
1. Temperature Sensors: thermistor type for terminal units and Resistance Temperature Device (RTD) with an integral transmitter type for all other sensors.
- a. Duct sensors shall be rigid or averaging type as shown on drawings. Averaging sensor shall be a minimum of 1 linear ft of sensing element for each sq ft of cooling coil face area.
 - b. Immersion sensors shall be provided with a separable well made of stainless steel, bronze or monel material. Pressure rating of well is to be consistent with the system pressure in which it is to be installed.
 - c. Space sensors shall be equipped with in-space User set-point adjustment, override switch, numerical temperature display on

sensor cover, and communication port. Match room thermostats. Provide a tooled-access cover.

- 1) Public space sensor: setpoint adjustment shall be only through the ECC or through the DDC system's diagnostic device/laptop. Do not provide in-space User set-point adjustment. Provide an opaque keyed-entry cover if needed to restrict in-space User set-point adjustment.
 - d. Outdoor air temperature sensors shall have watertight inlet fittings and be shielded from direct sunlight.
 - e. Room security sensors shall have stainless steel cover plate with insulated back and security screws.
 - f. Wire: Twisted, shielded-pair cable.
 - g. Output Signal: 4-20 ma.
- C. Static Pressure Sensors: Non-directional, temperature compensated.
1. 4-20 ma output signal.
 2. 0 to 5 inches wg for duct static pressure range.
 3. 0 to 0.25 inch wg for Building static pressure range.
- D. Water flow sensors: Refer to 25 10 10 ADVANCED UTILITY METERING SYSTEM.
- E. Flow switches:
1. Shall be either paddle or differential pressure type.
 - a. Paddle-type switches (liquid service only) shall be UL Listed, SPDT snap-acting, adjustable sensitivity with NEMA 4 enclosure.
 - b. Differential pressure type switches (air or water service) shall be UL listed, SPDT snap acting, NEMA 4 enclosure, with scale range and differential suitable for specified application.
- F. Current Switches: Current operated switches shall be self powered, solid state with adjustable trip current as well as status, power, and relay command status LED indication. The switches shall be selected to match the current of the application and output requirements of the DDC systems.
- G. Liquid level sensors (for Rainwater daytank):
1. Ultrasonic type.
 2. Install manufacturer-supplied gasket.
 3. Requires the installation of a manufacturer-provided USB device and manufacturer-provided software.
 4. The TC is responsible for furnishing all necessary interfacing hardware and software to communicate the liquid levels to the Building Automation System (BAS).
 5. Basis of Design: Flowline Model DL14 EchoPod.
- H. Tethered float switch (for Rainwater harvesting tank):
1. For control of SP-1.
 2. Piggyback-type electrical plug.
 3. Basis of Design: Flo-tec Model FP18-15BD.

2.11 CONTROL CABLES

- A. General:
1. Ground cable shields, drain conductors, and equipment to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments. Comply with Sections 27 05 26 and 26 05 26.
 2. Cable conductors to provide protection against induction in circuits. Crosstalk attenuation within the System shall be in

- excess of -80 dB throughout the frequency ranges specified.
3. Minimize the radiation of RF noise generated by the System equipment so as not to interfere with any audio, video, data, computer main distribution frame (MDF), telephone customer service unit (CSU), and electronic private branch exchange (EPBX) equipment the System may service.
 4. The as-installed drawings shall identify each cable as labeled, used cable, and bad cable pairs.
 5. Label system's cables on each end. Test and certify cables in writing to the VA before conducting proof-of-performance testing. Minimum cable test requirements are for impedance compliance, inductance, capacitance, signal level compliance, opens, shorts, cross talk, noise, and distortion, and split pairs on all cables in the frequency ranges used. Make available all cable installation and test records at demonstration to the VA. All changes (used pair, failed pair, etc.) shall be posted in these records as the change occurs.
 6. Power wiring shall not be run in conduit with communications trunk wiring or signal or control wiring operating at 100 volts or less.
- B. Analogue control cabling shall be not less than No. 18 AWG solid, with thermoplastic insulated conductors as specified in Section 26 05 21.
- C. Copper digital communication cable between the ECC and the B-BC and B-AAC controllers shall be 100BASE-TX Ethernet, Category 5e or 6, not less than minimum 24 American Wire Gauge (AWG) solid, Shielded Twisted Pair (STP) or Unshielded Twisted Pair (UTP), with thermoplastic insulated conductors, enclosed in a thermoplastic outer jacket, as specified in Section 27 15 00.
1. Other types of media commonly used within IEEE Std 802.3 LANs (e.g., 10Base-T and 10Base-2) shall be used only in cases to interconnect with existing media.
- D. Optical digital communication fiber, if used, shall be Multimode or Singlemode fiber, 62.5/125 micron for multimode or 10/125 micron for singlemode micron with SC or ST connectors as specified in TIA-568-C.1. Terminations, patch panels, and other hardware shall be compatible with the specified fiber and shall be as specified in Section 27 15 00. Fiber-optic cable shall be suitable for use with the 100Base-FX or the 100Base-SX standard (as applicable) as defined in IEEE Std 802.3.

2.12 THERMOSTATS

- A. Room thermostats controlling unitary standalone heating and cooling devices not connected to the DDC system shall have three modes of operation (heating - null or dead band - cooling). Thermostats for patient bedrooms shall have capability of being adjusted to eliminate null or dead band. Wall mounted thermostats shall have manufacturer's recommendation finish, setpoint range and temperature display and external adjustment:
1. Electronic Thermostats: Solid-state, microprocessor based, programmable to daily, weekend, and holiday schedules.
 - a. Public Space Thermostat: Public space thermostat shall have a thermistor sensor and shall not have a visible means of set point adjustment. Adjustment shall be via the digital controller to which it is connected.
 - b. Patient Room Thermostats: thermistor with in-space User set point adjustment and an on-casing room temperature numerical temperature display.

- c. Psychiatric Patient Room Sensors: Electronic duct sensor as noted under Article 2.4.
 - d. Battery replacement without program loss.
- B. Strap-on thermostats shall be enclosed in a dirt-and-moisture proof housing with fixed temperature switching point and single pole, double throw switch.
- C. Freezestats shall have a minimum of 300 mm (one linear foot) of sensing element for each 0.093 square meter (one square foot) of coil area. A freezing condition at any increment of 300 mm (one foot) anywhere along the sensing element shall be sufficient to operate the thermostatic element. Freezestats shall be manually-reset.

2.13 FINAL CONTROL ELEMENTS AND OPERATORS

- A. Fail Safe Operation: Control valves and dampers shall provide "fail safe" operation in either the normally open or normally closed position as required for freeze, moisture, and smoke or fire protection.
- B. Spring Ranges: Range as required for system sequencing and to provide tight shut-off.
- C. Power Operated Control Dampers (other than VAV Boxes): Factory fabricated, balanced type dampers. All modulating dampers shall be opposed blade type and gasketed. Blades for two-position, duct-mounted dampers shall be parallel, airfoil (streamlined) type for minimum noise generation and pressure drop.
- 1. Leakage: Except as specified in subparagraph 2 below, maximum leakage in closed position shall not exceed 7 L/S (15 CFMs) differential pressure for outside air and exhaust dampers and 200 L/S/ square meter (40 CFM/sq. ft.) at 50 mm (2 inches) differential pressure for other dampers.
 - 2. Frame shall be galvanized steel channel with seals as required to meet leakage criteria.
 - 3. Blades shall be galvanized steel or aluminum, 200 mm (8 inch) maximum width, with edges sealed as required.
 - 4. Bearing shall be nylon, bronze sleeve or ball type.
 - 5. Hardware shall be zinc-plated steel. Connected rods and linkage shall be non-slip. Working parts of joints shall be brass, bronze, nylon or stainless steel.
 - 6. Maximum air velocity and pressure drop through free area the dampers:
 - a. Smoke damper in air handling unit: 305 meter per minute (1000 fpm).
 - b. Duct mounted damper: 600 meter per minute (2000 fpm).
 - c. Maximum static pressure loss: 50 Pascal (0.20 inches water gauge).
- D. Smoke Dampers and Combination Fire/Smoke Dampers: Not applicable.
- E. Control Valves:
- 1. Valves shall be rated for a minimum of 150 percent of system operating pressure at the valve location but not less than 900 kPa (125 psig).
 - 2. Valves 50 mm (2 inches) and smaller shall be bronze body with threaded or flare connections.
 - 3. Valves 60 mm (2 1/2 inches) and larger shall be bronze or iron body with flanged connections.
 - 4. Brass or bronze seats except for valves controlling media above 100

- degrees C (210 degrees F), which shall have stainless steel seats.
5. Flow characteristics:
 - a. Three way modulating valves shall be globe pattern. Position versus flow relation shall be linear relation for steam or equal percentage for water flow control.
 - b. Two-way modulating valves shall be globe pattern. Position versus flow relation shall be linear for steam and equal percentage for water flow control.
 - c. Two-way 2-position valves shall be ball, gate or butterfly type.
 6. Maximum pressure drop:
 - a. Two position steam control: 20 percent of inlet gauge pressure.
 - b. Modulating Steam Control: 80 percent of inlet gauge pressure (acoustic velocity limitation).
 - c. Modulating water flow control, greater of 3 meters (10 feet) of water or the pressure drop through the apparatus.
 7. Two position water valves shall be line size.
- F. Damper and Valve Operators and Relays:
1. Electric operator shall provide full modulating control of dampers and valves. A linkage and pushrod shall be furnished for mounting the actuator on the damper frame internally in the duct or externally in the duct or externally on the duct wall, or shall be furnished with a direct-coupled design. Metal parts shall be aluminum, mill finish galvanized steel, or zinc plated steel or stainless steel. Provide actuator heads which allow for electrical conduit attachment. The motors shall have sufficient closure torque to allow for complete closure of valve or damper under pressure. Provide multiple motors as required to achieve sufficient close-off torque.
 - a. Minimum valve close-off pressure shall be equal to the system pump's dead-head pressure, minimum 50 psig for valves smaller than 4 inches.
 2. Electronic damper operators: Metal parts shall be aluminum, mill finish galvanized steel, or zinc plated steel or stainless steel. Provide actuator heads which allow for electrical conduit attachment. The motors shall have sufficient closure torque to allow for complete closure of valve or damper under pressure. Provide multiple motors as required to achieve sufficient close-off torque.
 - a. VAV Box actuator shall be mounted on the damper axle or shall be of the air valve design, and shall provide complete modulating control of the damper. The motor shall have a closure torque of 35-inch pounds minimum with full torque applied at close off to attain minimum leakage.
 3. See drawings for required control operation.

2.14 AIR FLOW CONTROL

- A. Airflow and static pressure shall be controlled via digital controllers with inputs from airflow control measuring stations and static pressure inputs as specified. Controller outputs shall be analog or pulse width modulating output signals. The controllers shall include the capability to control via simple proportional (P) control, proportional plus integral (PI), proportional plus integral plus derivative (PID), and on-off. The airflow control programs shall be factory-tested programs that are documented in the literature of the control manufacturer.

- B. Air Flow Measuring Station: refer to 23 73 00 INDOOR CENTRAL STATION AIR HANDLING UNITS.
- C. Static Pressure Measuring Station (AHU-2 only): shall consist of one or more static pressure sensors and transmitters along with relays or auxiliary devices as required for a complete functional system. The span of the transmitter shall not exceed two times the design static pressure at the point of measurement. The output of the transmitter shall be true representation of the input pressure with plus or minus 25 Pascal (0.1 inch) W.G. of the true input pressure:
1. Static pressure sensors shall have the same requirements as Airflow Measuring Devices except that total pressure sensors are optional, and only multiple static pressure sensors positioned on an equal area basis connected to a network of headers are required.
 2. For systems with multiple major trunk supply ducts, furnish a static pressure transmitter for each trunk duct. The transmitter signal representing the lowest static pressure shall be selected and this shall be the input signal to the controller.
 3. The controller shall receive the static pressure transmitter signal and CU shall provide a control output signal to the supply fan capacity control device. The control mode shall be proportional plus integral (PI) (automatic reset) and where required shall also include derivative mode.
 4. In systems with multiple static pressure transmitters, provide a switch located near the fan discharge to prevent excessive pressure during abnormal operating conditions. High-limit switches shall be manually-reset.
- D. Airflow Synchronization:
1. Systems shall consist of an air flow measuring station furnished by 23 73 00 INDOOR CENTRAL STATION AIR HANDLING UNITS for each supply and return fan array.
 2. The total flow signals from supply and return air shall be the input signals to the CU. This CU shall track the return air fan capacity in proportion to the supply air flow under all conditions.

2.15 VARIABLE SPEED MOTOR CONTROLLERS

- A. The scheduled variable speed motor controllers shall be furnished and installed by the Temperature Controls Contractor, unless noted otherwise.
- B. Shall be solid state, micro processor-based with adjustable frequency and voltage, three phase output capable of driving standard NEMA B design, three phase alternating current induction motors at full rated speed. The drives shall utilize a full wave bridge design incorporating diode rectifier circuitry with pulse width modulation (PWM). Other control techniques are not acceptable. Silicon controlled rectifiers (SCR) shall not be used in the rectifying circuitry. The drives shall be designed to be used on variable torque loads and shall be capable of providing sufficient torque to allow the motor to break away from rest upon first application of power.
- C. Unit shall be capable of operating within voltage parameters of plus 10 to minus 10 percent of line voltage, and be suitably rated for the full load amps of the maximum watts (HP) within its class.
- D. Operating and Design Conditions:
- Elevation: 500 feet AMSL

Temperatures: Maximum +90°F, Minimum -10°F
Relative Humidity: 95%
Drive Location: Mechanical Room

- E. Controllers shall have the following features:
1. Isolated power for control circuits.
 2. Manually re-settable motor overload protection for each phase.
 3. Adjustable current limiting circuitry to provide soft motor starting. Maximum starting current shall not exceed 200 percent of motor full load current.
 4. Independent acceleration and deceleration time adjustment, manually adjustable from 2 to 30 seconds. (Set timers to the equipment manufacturer's recommended time in the above range.)
 5. Provide 4 to 20 ma current follower circuitry for interface with mechanical sensor devices.
 6. Automatic frequency adjustment from 20 Hz to 60 Hz.
 7. Provide circuitry to initiate an orderly shutdown when any of the conditions listed below occur. The controller shall not be damaged by any of these electrical disturbances and shall automatically restart when the conditions are corrected. The drive shall be able to restart into a rotating motor operating in either the forward or reverse direction and matching that frequency.
 - a. Incorrect phase sequence.
 - b. Single phasing.
 - c. Over voltage in excess of 10 percent.
 - d. Under voltage in excess of 10 percent.
 - e. Running over current above 110 percent (shall not automatically reset for this condition.)
 - f. Instantaneous overcurrent above 150 percent (shall not automatically reset for this condition).
 - g. Surge voltage in excess of 1000 volts.
 - h. Short duration power outages of 12 cycles or less (i.e., distribution line switching, generator testing, and automatic transfer switch operations.)
 8. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.
 9. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Autospeed Search" feature is available and engaged.
 10. Bidirectional Autospeed Search: Capable of starting VFC into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.
- F. Minimum efficiency shall be 95 percent at 100 percent speed and 85 percent at 50 percent speed.
- G. The displacement power factor of the controller shall not be less than 95 percent under any speed or load condition.
- H. Controllers shall include a door interlocked fused safety disconnect switch or door interlocked circuit breaker switch which will disconnect all input power.
- I. Controller shall include a 3% line reactor, and RFI/EMI filter.
- J. The following accessories are to be door mounted:

1. AC Power on light.
 2. Ammeter (RMS motor current).
 3. HAND-OFF-AUTOMATIC switch.
 4. Manual speed control in HAND mode.
 5. System protection lights indicating that the system has shutdown and will not automatically restart.
 6. System protection light indicating that the system has shutdown but will restart when conditions return to normal.
 7. Manual variable speed controller by-pass switch.
 8. Diagnostic shutdown indicator lights for each shutdown condition.
 9. Provide two N.O. and two N.C. dry contacts rated 120 volts, 10 amperes, 60 HZ for remote indication of the following:
 - a. System shutdown with auto restart.
 - b. System shutdown without auto restart.
 - c. System running.
 10. Incorporate into each control circuit a 120-volt, time delay relay (ON delay), adjustable from 0.3-10 minutes, with transient protection. Provide transformer/s for the control circuit/s.
 11. Controller shall not add any current or voltage transients to the input AC power distribution system nor shall transients from other devices on the AC power distribution system affect the controller. Controllers shall be protected to comply with IEEE C37.90.1 and UL-508. Line noise and harmonic voltage distortion shall not exceed the values allowed by IEEE 519.
- K. Hardware and software to enable the BAS to monitor, control, and display controller status and alarms.
- L. Network Communications Ports: Ethernet and RS-485.
- M. Embedded BAS Protocols for Network Communications: As specified in Division 22.
- N. Bypass Operation: Manually transfers motor between power converter output and bypass circuit, manually, automatically, or both. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter. Transfer between power converter and bypass contactor and retransfer shall only be allowed with the motor at zero speed.
- O. Bypass Controller: Provide contactor-style bypass, arranged to isolate the power converter input and output and permit safe testing of the power converter, both energized and de-energized, while motor is operating in bypass mode. Motor overload protection shall be provided.
1. Bypass Contactor: Load-break NEMA-rated contactor.
 2. Input and Output Isolating Contactors: Non-load-break, NEMA-rated contactors.
 3. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

2.16 SYSTEM ACCESSORIES

- A. Provide the following accessories: Microsoft Surface Pro 3, 256 GB Intel i5, Surface Pro 3 Type Cover Black, Surface Ethernet Adapter, ZAGG Invisible Shield HD Screen Protector, Maroo Kope Series Leather Case.

PART 3 - EXECUTION**3.1 INSTALLATION****A. General:**

1. Examine project plans for control devices and equipment locations; and report any discrepancies, conflicts, or omissions to RE/COTR for resolution before proceeding for installation.
2. Install equipment, piping, wiring /conduit parallel to or at right angles to building lines.
3. Install all equipment and piping in readily accessible locations. Do not run tubing and conduit concealed under insulation or inside ducts.
4. Mount control devices, tubing and conduit located on ducts and apparatus with external insulation on standoff support to avoid interference with insulation.
5. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.
6. Run tubing and wire connecting devices on or in control cabinets parallel with the sides of the cabinet neatly racked to permit tracing.
7. Install equipment level and plumb.

B. Electrical Wiring Installation:

1. All wiring cabling shall be installed in conduits. Install conduits and wiring in accordance with Specification Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS. Conduits carrying control wiring and cabling shall be dedicated to the control wiring and cabling: these conduits shall not carry power wiring. Provide plastic end sleeves at all conduit terminations to protect wiring from burrs.
2. Install analog signal and communication cables in conduit and in accordance with Specification Section 26 05 21. Install digital communication cables in conduit and in accordance with Specification Section 27 15 00, COMMUNICATIONS HORIZONTAL CABLING.
3. Install conduit and wiring between operator workstation(s), digital controllers, electrical panels, indicating devices, instrumentation, miscellaneous alarm points, thermostats, and relays as shown on the drawings or as required under this section.
4. Install all electrical work required for a fully functional system and not shown on electrical plans or required by electrical specifications. Where low voltage (less than 50 volt) power is required, provide suitable Class B transformers.
5. Install all system components in accordance with local Building Code and National Electric Code.
 - a. Splices: Splices in shielded and coaxial cables shall consist of terminations and the use of shielded cable couplers. Terminations shall be in accessible locations. Cables shall be harnessed with cable ties.
 - b. Equipment: Fit all equipment contained in cabinets or panels with service loops, each loop being at least 300 mm (12 inches) long. Equipment for fiber optics system shall be rack mounted, as applicable, in ventilated, self-supporting, code gauge steel enclosure. Cables shall be supported for minimum sag.
 - c. Cable Runs: Keep cable runs as short as possible. Allow extra length for connecting to the terminal board. Do not bend flexible coaxial cables in a radius less than ten times the cable outside diameter.

- d. Use vinyl tape, sleeves, or grommets to protect cables from vibration at points where they pass around sharp corners, through walls, panel cabinets, etc.
 - 6. Conceal cables, except in mechanical rooms and areas where other conduits and piping are exposed.
 - 7. Permanently label or code each point of all field terminal strips to show the instrument or item served. Color-coded cable with cable diagrams may be used to accomplish cable identification.
 - 8. Grounding: ground electrical systems per manufacturer's written requirements for proper and safe operation.
- C. Install Sensors and Controls:
- 1. Temperature Sensors:
 - a. Install all sensors and instrumentation according to manufacturer's written instructions. Temperature sensor locations shall be readily accessible, permitting quick replacement and servicing of them without special skills and tools.
 - b. Calibrate sensors to accuracy specified, if not factory calibrated.
 - c. Use of sensors shall be limited to its duty, e.g., duct sensor shall not be used in lieu of room sensor.
 - d. Install room sensors permanently supported on wall frame. They shall be mounted at 1.5 meter (5.0 feet) above the finished floor.
 - e. Mount sensors rigidly and adequately for the environment within which the sensor operates. Separate extended-bulb sensors form contact with metal casings and coils using insulated standoffs.
 - f. Sensors used in mixing plenum, and hot and cold decks shall be of the averaging of type. Averaging sensors shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip.
 - g. All pipe mounted temperature sensors shall be installed in wells.
 - h. All wires attached to sensors shall be air sealed in their conduits or in the wall to stop air transmitted from other areas affecting sensor reading.
 - i. Permanently mark terminal blocks for identification. Protect all circuits to avoid interruption of service due to short-circuiting or other conditions. Line-protect all wiring that comes from external sources to the site from lightning and static electricity.
 - 2. Pressure Sensors:
 - a. Install duct static pressure sensor tips facing directly downstream of airflow.
 - b. Install high-pressure side of the differential switch between the pump discharge and the check valve.
 - c. Install snubbers and isolation valves on steam pressure sensing devices.
 - 3. Actuators:
 - a. Mount and link damper and valve actuators according to manufacturer's written instructions.
 - b. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed position.
 - c. Check operation of valve/actuator combination to confirm that actuator modulates valve smoothly in both open and closed

position.

1. Flow Switches:
 - a. Install flow switch according to manufacturer's written instructions.
 - b. Mount flow switch a minimum of 5 pipe diameters up stream and 5 pipe diameters downstream or 600 mm (2 feet) whichever is greater, from fittings and other obstructions.
 - c. Assure correct flow direction and alignment.
 - d. Mount in horizontal piping-flow switch on top of the pipe.
- D. Installation of network:
 1. Ethernet:
 - a. The network shall employ Ethernet LAN architecture, as defined by IEEE 802.3. The Network Interface shall be fully Internet Protocol (IP) compliant allowing connection to currently installed IEEE 802.3, Compliant Ethernet Networks.
 - b. The network shall directly support connectivity to a variety of cabling types. As a minimum provide the following connectivity: 100 Base TX (Category 5e cabling) for the communications between the ECC and the B-BC and the B-AAC controllers.
 2. Third party interfaces: Contractor shall integrate real-time data from building systems by other trades and databases originating from other manufacturers as specified and required to make the system work as one system.
- E. Installation of digital controllers and programming:
 1. Provide a separate digital control panel for each major piece of equipment, such as air handling unit, chiller, pumping unit etc. Points used for control loop reset such as outdoor air or space temperature could be located on any of the remote control units.
 2. Provide sufficient internal memory for the specified control sequences and trend logging. There shall be a minimum of 25 percent of available memory free for future use.
 3. System point names shall be modular in design, permitting easy operator interface without the use of a written point index.
 4. Provide software programming for the applications intended for the systems specified, and adhere to the strategy algorithms provided.
 5. Provide graphics for each piece of equipment and floor plan in the building. This includes each chiller, cooling tower, air handling unit, fan, terminal unit, boiler, pumping unit etc. These graphics shall show all points dynamically as specified in the point list.

3.2 SYSTEM VALIDATION AND DEMONSTRATION

- A. As part of final system acceptance, a system demonstration is required (see below). Prior to start of this demonstration, the contractor is to perform a complete validation of all aspects of the controls and instrumentation system.
- B. Validation:
 1. Prepare and submit for approval a validation test plan including test procedures for the performance verification tests. Test Plan shall address all specified functions of the ECC and all specified sequences of operation. Explain in detail actions and expected results used to demonstrate compliance with the requirements of this specification. Explain the method for simulating the necessary conditions of operation used to demonstrate performance of the system. Test plan shall include a test check list to be used by the Installer's agent to check and initial that each test has been

successfully completed. Deliver test plan documentation for the performance verification tests to the owner's representative 30 days prior to start of performance verification tests. Provide draft copy of operation and maintenance manual with performance verification test.

2. After approval of the validation test plan, installer shall carry out all tests and procedures therein. Installer shall completely check out, calibrate, and test all connected hardware and software to insure that system performs in accordance with approved specifications and sequences of operation submitted. Installer shall complete and submit Test Check List.

C. Demonstration:

1. System operation and calibration to be demonstrated by the installer in the presence of the Architect or VA's representative on random samples of equipment as dictated by the Architect or VA's representative. Should random sampling indicate improper commissioning, the owner reserves the right to subsequently witness complete calibration of the system at no addition cost to the VA.
2. Demonstrate to authorities that all required safeties and life safety functions are fully functional and complete.
3. Make accessible, personnel to provide necessary adjustments and corrections to systems as directed by balancing agency.
4. Witnessed demonstration of ECC functions shall consist of:
 - a. Running each specified report.
 - b. Display and demonstrate each data entry to show site specific customizing capability. Demonstrate parameter changes.
 - c. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.
 - d. Execute digital and analog commands in graphic mode.
 - e. Demonstrate DDC loop precision and stability via trend logs of inputs and outputs (6 loops minimum).
 - f. Demonstrate EMS performance via trend logs and command trace.
 - g. Demonstrate scan, update, and alarm responsiveness.
 - h. Demonstrate spreadsheet/curve plot software, and its integration with database.
 - i. Demonstrate on-line user guide, and help function and mail facility.
 - j. Demonstrate digital system configuration graphics with interactive upline and downline load, and demonstrate specified diagnostics.
 - k. Demonstrate multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
 - l. Demonstrate class programming with point options of beep duration, beep rate, alarm archiving, and color banding.

3.3 SEQUENCES OF OPERATION

A. AIR HANDLING SYSTEMS

1. System is a 100% outside air, multi-zone, single duct, variable air volume (VAV) system. The VAV air handler includes a supply fan, exhaust fan, hot water preheat coil, chilled water cooling coil, outside air damper, return damper, relief damper, and steam humidifier (humidifier on AHU-2 only). Terminal units are chilled beams (AHU-1) and single duct VAV with hot water reheat coils (AHU-2). The system will operate in occupied mode. System components

shall operate in response to the BAS in accordance with these listed operational requirements, control sequences, and set points, subject to safeties.

2. Equipment (AHU fans, pumps, etc.) with integral VFD/starter HAND-OFF-AUTO switches, (or with separate H-O-A switches provided by Division 26) operational safety interlocks and limit controls shall remain in effect in each switch position, with summary as follows:
 - a. AUTO: Fan/pump operates in accordance with system control programs, subject to safeties.
 - b. OFF: Fan/pump off.
 - c. HAND/VFD BY-PASS: Fan/pump on, speed manually controlled at VFD (where applicable), subject to safeties.
3. Occupied Mode:
 - a. When the on/off/auto switch located in the BAS panel is in the Auto position, the system will be started and stopped through the BAS controller. AHU will run 24 hours/day, 7 days/week, with no unoccupied mode.
 - b. Unit supply and exhaust fans operate at maximum airflow setpoint during occupied hours to maintain occupied temperature setpoint in each zone. Zone dampers (external to AHU) are in the open position during maximum airflow mode.
 - c. Fan volume control: Supply and exhaust fan speed is modulated by ECM motors. Airflow stations in supply and return path monitor actual airflow. Fan speed is automatically adjusted to compensate for filter loading to maintain airflow setpoint.
 - d. There shall be one (1) static pressure sensor located approximately 2/3 downstream from fan to the last terminal unit. Supply duct static pressure as sensed from the sensor shall be maintained by modulating the supply fan array ECM motors (0-10 VDC). Static pressure shall be maintained at a maximum setpoint of 1.5" (adj.) High static limit sensor shall limit the ECM motor to prevent overpressurization of supply ductwork above a setpoint of 4.5" (adj.).
 - e. Static Pressure Reset Strategy: Reset the static pressure setpoint from 1.5" (adj.) (or alternate maximum setpoint as determined by balancing contractor) to 0.5" based on cooling demand and outdoor air temperature. Establish PID loop to maintain stable operation of this sequence.
 - 1) Outdoor air temperature below 60 deg F: Poll ten critical boxes as determined by the design engineer and reset the discharge static pressure to 0.5" when the box with the greatest cooling demand is less than 20% cooling output to 1.5" (adj.) when the box with the greatest cooling demand is at 95% output.
 - 2) Outdoor air temperature above 60 deg F: maintain the discharge static pressure setpoint at 1.5" w.c. (adj.) (or alternate maximum setpoint as determined by balancing contractor).
 - f. Whenever the outside air temperature is less than the return air temperature, the AHU controller shall be indexed to allow the use of OSA free cooling (economizer = 1st stage of cooling). The outside air damper shall open, the relief damper shall modulate open and the return damper shall modulate closed, in sequence, to maintain the discharge air setpoint. The return damper shall remain fully open and the relief damper shall remain fully closed unless OSA free cooling is required.

- g. Discharge Air Reset Strategy: Reset the discharge air setpoint based upon cooling demand by polling (10) critical zones as determined during commissioning. Reset the discharge air setpoint from 65 deg F when the box with the highest cooling demand is less than 50%, to 55 deg F when the box with the highest cooling demand is at 95% output.
- h. Chilled Water Coil: Chilled-water cooling shall be the second stage cooling source for the AHU. Modulate the chilled water valve to maintain the discharge air setpoint temperature when the first stage cooling source (economizer cooling) can no longer maintain the setpoint. Modulate the valve open upon a rise in discharge above setpoint and closed upon a drop in discharge below setpoint. Lock the valve closed below 53 deg F outdoor air temperature.
 - 1) Programming shall prohibit simultaneous operation of cooling and preheat coils.
 - 2) Initial discharge setpoint = 65 deg F, then follow the discharge air reset schedule.
- i. Heating Coil: Modulate the heating water valve to maintain the discharge air setpoint temperature. Modulate the valve open upon a drop in discharge air temperature and closed upon a rise in discharge air temperature above setpoint. Lock the valve closed when outdoor air temperature is above 45 deg F (adj.).
 - 1) Programming shall prohibit simultaneous operation of cooling and preheat coils.
 - 2) Initial discharge setpoint = 65 deg F, then follow the discharge air reset schedule.
- j. Freeze protection strategy: An auto reset freezestat (FZ#1) on entering side of the heating coil, set at 36 deg F (adj.) shall open the hot water valve, insure either HWP-1 or HWP-2 is operational and initiate an alarm to the BAS. A manual freezestat (FZ#2) on the leaving side of the heating coil shall stop the AHU anytime the temperature of the mixed air drops below the setpoint of 32 deg F (adj.). Both freezestats shall indicate an alarm to the BAS. Provide sufficient quantity of devices to adequately cover the entire face of the coil.
- k. Filter maintenance strategy: Excessive filter pressure drop on the filters shall alarm the BAS as monitored by individual analog-type differential pressure sensors rated for pressures of 0-1" w.c.
- l. Whenever the unit is off, the following shall occur:
 - 1) Outside air and relief air dampers shall close, and return damper shall open.
 - 2) Preheat coil valve shall close.
 - 3) Supply fan array shall shut down.
 - 4) Return fan array shall shut down.
 - 5) Control system shall be de-energized.
- m. Outside Air Dampers, Automatic Return and Relief:
 - 1) Dedicated actuators shall operate outside, return and relief air dampers in accordance with system operating status and supply and return air temperatures.
 - a) Outside Air Damper:
 - (1) Modulating.
 - (2) Closed when system is not operating.

- (3) Modulating damper controlled in response to discharge temperature required, time of day, outside air ambient sensor, to modulate between minimum outside air and free cooling (economizer). Economizer cycle shall be utilized when outside air temperature is at or below return air temperature.
 - b) Return air dampers:
 - (1) Modulating.
 - (2) The damper shall be modulated to maintain -0.5 inches w.c. (adjustable) static pressure relative difference between mixed air plenum and outside ambient air static pressure. A shielded mixed air plenum static pressure sensor and a shielded outside air static pressure sensor shall be used.
 - c) Relief damper:
 - (1) Modulating.
 - (2) Damper operates shall track inverse operation of return damper, off common signal. Relief damper fully open when return air damper is fully closed.
 - n. Zone dampers:
 - (1) Two motorized dampers on first floor shall be open at all times during occupancy in the two respective zones (AHU-1 only).
- 4. Heat exchanger bypass dampers:
 - a. Economizer: As outside air temperature rises toward supply air temperature setpoint, dampers bypass return air as required to maintain supply air setpoint without use of mechanical cooling.
 - b. Frost prevention: As outside air temperature drops, dampers bypass air as needed to prevent formation of frost on heat exchanger.
 - 5. Humidification (AHU-2 only): During dry, cold weather conditions the steam humidifier adds moisture to the outside air to maintain humidity setpoint of 30% (adj.) in representative spaces and at return air humidity sensor. A setpoint adjust signal is conveyed to the steam humidifier based on the humidity sensor that is in the greatest need of humidification.
 - 6. Dehumidification: During humid weather conditions the cooling coil removes moisture from the outside air by cooling the air to the dewpoint to maintain humidity setpoint in representative spaces, in the return air, and to prevent condensation in the surfaces of the chilled beams. This is followed by reheat at the air handler heating coil to increase the supply air temperature to its setpoint.
 - 7. Filters: Pre and after filter (and final filter, AHU-2 only) pressure drop is monitored with a differential pressure switch and an alarm is sent when setpoint is reached.
 - 8. Unoccupied Mode:
 - a. Unit supply and exhaust fans operate at minimum airflow setpoint and external zone dampers are closed during unoccupied hours to maintain setpoint requirements as noted for the following spaces.
 - 1) Clean Utility Rooms.

- 2) Soiled Utility Rooms.
 - b. Night Low (high) limit: Unit runs at maximum airflow setpoint when any 3 (adj.) zone sensors call for heating (cooling) during unoccupied period, and until all zones have exceeded their unoccupied heating (cooling) setpoints by 3 degrees F (adj.), at which point unit returns to occupied mode.
 - c. Temporary occupied: When any space sensor is overridden to occupied mode, unit shall operate at maximum airflow setpoint until that zone times out (adj.).
 - d. Building warmup/cool-down: Unit operates at maximum airflow setpoint. An optimum start routine determines start time based on building warmup or cool-down requirements.
 - e. Zone dampers:
 - (1) Two motorized dampers on first floor shall be closed at all times during unoccupied mode in the two respective zones (AHU-1 only).
9. Fire Protection:
- a. Duct smoke detector signal from fire alarm panel to shut down AHU system and close associated fire/smoke and to meet NFPA 90A and IMC 606. BAS annunciates when a building fire alarm AHU shutdown has occurred.
 - b. The BAS panel connects to one of two relays in series provided by Division 28 for damper actuation in conjunction with air handler operational schedule. BAS sends a signal open or close all the duct mounted combination fire/smoke dampers served by the AHU, whenever the unit is to be started or stopped. Program a time delay into the BAS to prevent the unit fan(s) from starting until a sufficient time has lapsed for the fire/smoke dampers to open. Similarly, BAS sends a signal to the fire/smoke damper relays, after a time delay, to close the dampers after the unit fan(s) are commanded off. Coordinate with Division 28 for Fire Alarm interface and combination fire/smoke dampers.
 - c. Duct smoke and/or area smoke detector signal to shut down AHU system, close associated fire/smoke and smoke dampers, and shut down interlocked equipment to meet NFPA 90A and IMC 606.
 - d. Smoke detector and relay and 120 volt circuit to relay, provided by under Division 26.
 - e. Area smoke detector signal to stop system through starter circuits, and shut down interlocked equipment to meet NFPA 90A and IMC 606.
10. Input/Output Point Monitoring Summary:
- a. As a minimum, the following points and features are to be monitored and alarmed. Control Contractor shall provide additional points necessary to accomplish the sequence of operation and interface with other control equipment.
 - b. Inputs:
 - 1) AHU Supply fan run status (BI).
 - 2) AHU Return fan run status (BI).
 - 3) Supply duct static pressure (AI).
 - 4) Outside air temperature (AI).
 - 5) AHU Return air temperature (AI).
 - 6) AHU Mixed air temperature (AI).
 - 7) AHU Supply air temperature (AI).
 - 8) Supply air flow quantity (AI).
 - 9) Return air flow quantity (AI).

- 10) Mixed air plenum pressure (AI).
- 11) Outdoor air pressure (AI).
- 12) Building static pressure (AI).
- 13) AHU Filter Differential Pressure (AHU-1, AI, 2 thus).
- 14) AHU Filter Differential Pressure (AHU-2, AI, 3 thus).
- 15) Heat exchanger discharge temperature (AI).
- 16) Heat exchanger discharge humidity (AI).
- c. Outputs:
 - 1) AHU Supply fan start/stop (BO).
 - 2) AHU Return fan start/stop (BO).
 - 3) Supply fan array modulation (BO).
 - 4) Return fan array modulation (BO).
 - 5) Outside air damper (AO).
 - 6) Return air damper (AO).
 - 7) Relief air damper (AO).
 - 8) Preheat Coil Valve (AO).
 - 9) Cooling Coil Valve (AO).
 - 10) Supply duct static pressure (AO).
 - 11) Supply air damper, 1st flr N (AHU-1, BO).
 - 12) Supply air damper, 1st flr S (AHU-1, BO).
 - 13) Supply air damper, Basement (AHU-1, BO).
 - 14) Humidifier steam control valve (AHU-2 only, AO).
 - 15) Heat exchanger bypass damper (AO).
- d. General Alarms (any unscheduled fan shutdown):
 - 1) Air handling unit control panel communication failure.
 - 2) Mixed air high/low temperature.
 - 3) Low mixed air plenum pressure.
 - 4) AHU Supply fan failure (annunciated).
 - 5) AHU Return fan failure (annunciated).
 - 6) Freeze warning (annunciated).
 - 7) Freeze shutdown (annunciated).
 - 8) Supply air low temperature limit (annunciated).
 - 9) AHU Filter Differential Pressure High -0.75 inches w.c. (two thus).
 - 10) Supply duct static pressure high/low limit
 - a) Alarm at excess of 15% above or below setpoint.
 - 11) Zone temperature high/low limit
 - a) Alarm at excess of 3% above or below setpoint.
- 11. Terminal Units (AHU-1):
 - a. Chilled beams receive both heating and chilled water for cooling and heating. Either heating or cooling, but not both, are added at the beam as needed to meet space temperature setpoint.
 - b. During occupied mode, a constant amount of primary air is supplied to each beam whenever the air handler runs to meet ventilation requirements and to meet cooling/heating load.
 - c. A deadband is maintained between heating and cooling setpoints (both occupied and unoccupied modes).
 - d. Input/Output Point Monitoring Summary:
 - 1) As a minimum, the following points and features are to be monitored and alarmed. Control Contractor shall provide additional points necessary to accomplish sequence of operation and interface with other control equipment.
 - 2) Inputs:
 - a) Space Temperatures (AI) (each zone).
 - b) Space occupancy sensor (BI), where shown on Electrical

Drawings.

- 3) Outputs:
 - a) Chilled beam heating coil valve (AO) (each zone).
 - b) Chilled beam cooling coil valve (AO) (each zone).
- 4) General Alarms:
 - a) Zone temperature high/low limit.
 - (1) Alarm at excess of 3% above or below setpoint.

12. Terminal Units (AHU-2):

- a. Control damper and coil control valve at coil shall modulate in response to Space Sensor for that zone, in accordance with heating, cooling, and deadband temperature setpoints.
- b. Terminal unit zone temperature control programming shall include multiple cooling setpoints for allowing lower space temperatures when economizer cooling is utilized.
- c. Provide sensor downstream of each terminal unit to monitor supply air temperature.
- d. Provide dual maximum and minimum air volume setpoints utilizing a velocity pressure sensor in the terminal inlet. Controls shall be capable of maintaining accurate air volume delivery at all points between scheduled two maximum and minimum flow rates. Individual setpoints and modes of operation shall be adjustable through the operator workstation.
- e. Occupied Operation:
 - 1) Zone temperature setpoints maintained by modulating terminal unit air valves and heating water valves, in conjunction with modulating components at central unit to maintain setpoints listed for specific system.
 - 2) Heating setpoint = 70 deg F.
 - 3) Cooling setpoint = 75 deg F.
 - 4) Damper Position Summary:
 - a) Cooling: Damper modulates to meet cooling requirement.
 - b) Dead-band region: Damper at minimum setpoint.
 - c) Heating: Damper to modulate to minimum setpoint before opening heating coil valve.
 - 5) Valve Position:
 - a) Cooling: Control valve positioned to stop water flow through coil.
 - b) Dead-band region: Control valve positioned to stop water flow through coil.
 - c) Heating: Control valve modulates to meet heating requirement.
 - 6) VAV box temperature control sequence of operation shall utilize a customized cascade control strategy; pre-programmed factory sequences are not acceptable. The room temperature primary controller shall reset the airflow secondary controller and discharge air temperature secondary controller setpoints. The airflow secondary controller shall modulate the VAV box damper to maintain the airflow setpoint. The discharge air temperature secondary controller shall modulate the heating valve to maintain the discharge air temperature setpoint.

- 7) Cooling Mode: On a rise in space temperature above the cooling setpoint, the unit shall be in cooling mode. The heating valve shall remain closed and the room temperature primary controller shall reset the airflow secondary controller setpoint from minimum airflow to the cooling maximum airflow.
 - 8) Deadband Mode: If the space temperature is between the cooling and heating space temperature setpoints, the heating valve shall remain closed and the airflow secondary controller shall modulate the VAV box damper to maintain the minimum airflow setpoint.
 - 9) Heating Mode: On a drop in space temperature below the heating setpoint the unit shall be in heating mode and limit the discharge air temperature to 95 deg F (adj.) to minimize stratification. From 0% to 50% heating signal, the room temperature primary controller shall reset the discharge air temperature secondary controller setpoint from 55 deg F to 95 deg F (adj.) and the airflow secondary controller shall modulate the VAV box damper to maintain the minimum airflow setpoint. From 50% to 100% heating signal, the discharge air secondary controller shall modulate the heating valve to maintain the discharge air temperature at 95 deg F (adj.) and the room temperature primary controller shall reset the airflow secondary controller setpoint from the minimum airflow to the heating maximum airflow.
 - 10) On a predetermined schedule (every 108 days, adj.), VAV damper shall modulate to 0% and then be allowed to reset for calibration purposes.
 - 11) TU-2-5 and TU-2-8 only: Upon operation of the exhaust fans EF-2 and EF-3, the terminal unit airflows shall increase as follows: TU-2-5, 265 cfm additional; TU-2-8, 765 cfm additional. When the exhaust fans are de-energized, the respective terminal unit shall revert to normal occupied mode.
- f. Unoccupied Operation During Occupied Hours:
- 1) Zones included: Refer to all locations on electrical Drawings where indicated as having "Occupancy Sensors".
 - 2) Occupancy sensors provided under Division 26.
 - 3) If, after 30 minutes, no occupants are sensed in given area, VAV terminal units serving that area shall close, subject to maintaining temperature in accordance with 60 deg F heating space temperature and 80 degree cooling space temperature setpoints. Terminal units shall return to Occupied Mode operation immediately upon sensing occupancy in space during normally occupied hours.
 - 4) For zones with more than one room, occupancy sensors shall be connected in series for single zone input to equipment controller.
- g. Input/Output Point Monitoring Summary:
- 1) As a minimum, the following points and features are to be monitored and alarmed. Control Contractor shall provide additional points necessary to accomplish sequence of operation and interface with other control equipment.
 - 2) Inputs:
 - a) Terminal unit supply air temperature (AI).
 - b) Terminal unit air flow, cfm (AI).

- c) Space Temperatures (AI) (each zone).
- d) Space occupancy sensor (BI), where shown on Electrical Drawings.
- 3) Outputs:
 - a) Heating Coil Valve (AO) (each zone).
 - b) Terminal unit damper position (AO) (each zone).
- 4) General Alarms:
 - a) Zone temperature high/low limit.
 - (1) Alarm at excess of 3% above or below setpoint.

B. EXHAUST FANS

1. (All exhaust fans exceeding 300 cfm) On fan on command, automatic damper opens and fan starts following a delay (adjustable). On fan off command, the fan stops and the automatic damper closes following a delay (adjustable). Operation of the exhaust fan shall be monitored with a current transformer switch.
2. (EF-1,2,3) On fan command on, fan starts. On fan off command, fan stops. Operation of the exhaust fan shall be monitored with a current transformer switch.
3. (EF-4 only) Fan is controlled from a reverse-acting wall-mounted room sensor. On fan on command, two automatic dampers open (exhaust damper and its respective AHU-1 supply damper) and fan starts following a delay (adjustable). On fan off command, the fan stops and the automatic damper closes following a delay (adjustable). Operation of the exhaust fan shall be monitored with a current transformer switch.
4. Input/Output Point Monitoring Summary:
 - a. As a minimum, the following points and features are to be monitored and alarmed. Control Contractor shall provide additional points necessary to accomplish sequence of operation and interface with other control equipment.
 - b. Inputs:
 - 1) (EF-1 through EF-4) Fan run status (BI).
 - c. Outputs:
 - 1) (EF-1 through EF-4) Fan start/stop (BO).
 - 2) (EF-1 through EF-4) Automatic Damper open/close (BO).
 - d. General Alarms:
 - 1) Fan run failure (annunciated).

C. ACU-1, ACU-2

1. These systems are being supplied with a manufacturer-provided thermostat. Temperature controls contractor is responsible for connecting these thermostats complete and checking for proper equipment operation.
2. An additional DDC room sensor is required for the spaces that this equipment serves as shown on the Drawings. This sensor is for monitoring purposes only.
3. Input/Output Point Monitoring Summary:
 - a. As a minimum, the following points and features are to be monitored and alarmed. Control Contractor shall provide additional points necessary to accomplish sequence of operation and interface with other control equipment.
 - b. Inputs:

- 1) Space Temperatures (AI) (each zone).
- c. Outputs:
 - 1) N/A.
- d. General Alarms:
 - 1) Zone temperature high/low limit.
 - a) Alarm at excess of 3% above or below setpoint.

D. UNIT HEATERS (INCLUDES FAN COIL UNITS)

- 1. Relay or starter with HAND-OFF-AUTO provided under Division 26.
- 2. Heating water control valve opens and unit heater fan operates in response to wall mounted space sensor subject to safeties:
 - a. Unit Heater on = 50 deg F.
 - b. Unit Heater off = 65 deg F.
- 3. Unit Heater operation monitored with a current transformer switch.
- 4. Input/Output Point Monitoring Summary:
 - a. As a minimum, the following points and features shall be monitored and alarmed. Control Contractor shall add additional points necessary to accomplish sequence of operation and interface with other control equipment.
 - b. Inputs:
 - 1) Unit Heater run status (BI).
 - c. Outputs:
 - 1) Unit Heater on/off (BO).
 - 2) Heating Water valve position (BO).
 - d. General Alarms (any unscheduled Unit Heater shutdown):
 - 1) Unit Heater failure (annunciated).

E. HEATING WATER SYSTEM

- 1. Steam-to-water heat exchangers (lead/lag) receive low pressure steam from central plant and generate heating water for space heating.
 - 1) Lead heat exchanger is manually selected by closing isolation valves. Only one heat exchanger is ever used at one time. Provide a selector switch on the computer graphic screen indicating which heat exchanger is in operation. This switch ensures that the control valves serving the lag heat exchanger are completely closed.
 - 2) Each heat exchanger is served by two control valves. The first stage of heating is provided with control valve with 1/3 capacity. Second stage is provided with the 2/3 capacity valve, and 3rd stage uses both.
 - 3) Heating water setpoint
 - a) The hot water supply temperature setpoint shall be reset using a trim and respond algorithm based on heating requirements.
 - b) As the facility's hot water valves open beyond a user definable threshold (90% open, typ.), the setpoint shall reset to a higher value (adj.). Once the hot water coils are satisfied (valves closing) then the setpoint shall gradually lower over time to reduce heating energy losses from piping.
 - c) Hot water supply temperature range shall be 110 to 140 degrees F (adj.).
- 2. Heating water loop with variable speed pumps (lead/lag) and

differential pressure station circulates water to all heating elements in building.

a. Pump selection:

- 1) The two pumps operate in a lead/lag fashion and are controlled by the BMS based on the loop differential pressure.
- 2) The BMS shall enable the VFD and provide speed reference to maintain system pressure.
- 3) When an air handler is enabled the lead pump is commanded ON.
- 4) If the lead pump does not proof ON (via VFD current output), the lag pump is commanded ON and the lead pump is commanded OFF - an alarm is generated.
- 5) If the lag pump does not proof ON (via VFD current output), an alarm is generated. The enable command is maintained on to allow the system to run if the VFD clears.
- 6) The BMS rotates the lead/lag pump assignment based on one of the following screen selectable conditions:
 - a) Manually, through a software switch
 - b) When the lead pump runtime exceeds 300 hours (adj.), the lag pump will become the lead pump.
 - c) With a schedule, as determined by user.

b. Heating water differential pressure control

- 1) The lead pump VFD speed is ramped using a PI algorithm to maintain the secondary loop differential pressure at 3 psi (adj.).
- 2) If the lead pump VFD speed rises above 90% (adj.), the lag pump is enabled and its speed is set to match the lead pump speed. The two pumps continue to operate in unison to maintain the differential pressure setpoint.
- 3) If the speed of the lead and lag pump falls to 30% (adj.), the lag pump is disabled and the lead pump operates alone.
- 4) The BMS incorporates adjustable pump enable/disable delay timers to prevent short cycling. These timers are tuned during the startup and commissioning process.
- 5) The VFD minimum speed shall not be set below 30%.

3. Equipment (AHU fans, pumps, etc.) with integral starter HAND-OFF-AUTO switches, (or with separate H-O-A switches provided by Division 26) operational safety interlocks and limit controls shall remain in effect in each switch position, with summary as follows:

- a. AUTO: Fan/pump operates in accordance with system control programs, subject to safeties.
- b. OFF: Fan/pump off.
- c. HAND: Fan/pump on, subject to safeties.

4. Input/Output Point Monitoring Summary:

- a. As a minimum, the following points and features are to be monitored and alarmed. Control Contractor shall add additional points necessary to accomplish sequence of operation and interface with other control equipment.
- b. Inputs:
 - 1) HWP-1 Pump run status (BI).
 - 2) HWP-2 Pump run status (BI).
 - 3) Building heating water supply temperature (AI).
 - 4) Building heating water return temperature (AI).
 - 5) Heat exchanger HX-1 steam valve position feedback, 1/3 capacity (AI).

- 6) Heat exchanger HX-1 steam valve position feedback, 2/3 capacity (AI).
 - 7) Heat exchanger HX-2 steam valve position feedback, 1/3 capacity (AI).
 - 8) Heat exchanger HX-2 steam valve position feedback, 2/3 capacity (AI).
 - 9) Heating water differential pressure (AI).
 - 10) Heating water system pressure at makeup, (BI).
- c. Outputs:
- 1) HWP-1 Pump start/stop (BO).
 - 2) HWP-2 Pump start/stop (BO).
 - 3) Building heating water supply setpoint (AO) (to BMS).
 - 4) Heating water system enable/disable (BO) (to BMS).
 - 5) Heat exchanger HX-1 steam control valve position, 1/3 capacity (AO).
 - 6) Heat exchanger HX-1 steam control valve position, 2/3 capacity (AO).
 - 7) Heat exchanger HX-2 steam control valve position, 1/3 capacity (AO).
 - 8) Heat exchanger HX-2 steam control valve position, 2/3 capacity (AO).
- d. General Alarms:
- 1) Pump failure to start on command.
 - 2) Unscheduled pump shutdown.
 - 3) Boiler control panel communication failure (annunciated).
 - 4) Boiler heating water supply high/low temperature (annunciated).
 - 5) Alarm at excess of 10% above or below setpoint.
 - 6) Building heating water supply high/low temperature (annunciated)
 - 7) Alarm at excess of 10% above or below setpoint.

F. CHILLED WATER SYSTEM

1. Chiller CH-1, variable speed primary pumps (lead/lag), variable speed secondary pumps (lead/lag), tertiary pumps for chilled beams (lead/lag). Chiller provides cooling when waterside economizer cannot maintain chilled water supply water setpoint and/or when dehumidification is required. System components shall respond to the BAS in accordance with these listed operational requirements, subject to safeties and packaged controls.
2. Chiller operates in accordance with internal operational requirements as controlled from integrated microprocessor control panel, and BAS sequencing, time of day and water temperature reset schedules, subject to safeties.
 - a. Field wire interlock to chilled water flow switch to prove chilled water flow.
 - b. Connect to Chiller control panel for monitoring and control from BAS.
 - c. Operation of chiller shall be monitored through the Bacnet communications interface.
3. First stage cooling: Waterside economizer is enabled upon a call for space cooling and outside air temperature is low enough to provide 57 degree F secondary chilled water (see waterside economizer sequence below).
4. Second stage cooling: Chilled water system shall be enabled to

- operate when the following are true:
- a. At least one chilled water coil calls for cooling.
 - b. The outside air temperature is greater than 55 deg F (adjustable).
5. Equipment (Pumps, etc.) with integral VFD/starter HAND-OFF-AUTO switches, (or with separate H-O-A switches provided by Division 26) operational safety interlocks and limit controls shall remain in effect in each switch position, with summary as follows:
- a. AUTO: Pump operates in accordance with system control programs, subject to safeties.
 - b. OFF: Fan/pump off.
 - c. HAND/VFD BY-PASS: Fan/pump on, [speed manually controlled at VFD (where applicable), subject to safeties.
6. Primary chilled water pump operation:
- a. The two primary chilled water pumps operate in a lead/lag fashion and the lead pump is enabled by the BMS anytime the chiller is called to run.
 - b. The primary chilled water pump shall start prior to the chiller being enabled and shall stop only after the chiller is disabled. The chilled water pump shall have both a user adjustable delay on start and a user adjustable delay on stop. The delay times shall be set appropriately to allow for orderly chilled water system start-up, shutdown and sequencing.
 - c. If the lead pump does not proof ON (via current signal), the lag pump is commanded ON and the lead pump is commanded OFF - an alarm is generated.
 - d. If the lag pump does not proof ON (via current signal), an alarm is generated. The enable command is maintained on to allow the system to run if the condition clears.
 - e. The BMS rotates the lead/lag pump assignment based on one of the following screen selectable conditions:
 - 1) Manually, through a software switch
 - 2) When the lead pump runtime exceeds 300 hours (adj.), the lag pump will become the lead pump.
 - 3) With a schedule, as determined by user.
7. Primary chilled water temperature setpoint control:
- a. Initial setpoint upon chiller startup:
 - 1) If chiller is enabled due to inability of waterside economizer to maintain secondary chilled water supply setpoint, then at startup the leaving water temperature setpoint shall be as high as the chiller manufacturer allows, but no higher than 57 degrees F.
 - 2) If chiller is enabled due to a call for dehumidification from humidity sensors then at startup the leaving water temperature setpoint shall be 44 degrees F. (adj.). This shall override the other initial setpoint requirements.
 - 3) If chiller is enabled due to a call for cooling at an air handler cooling coil, then at startup the leaving water temperature setpoint shall be same as in 1) above.
 - b. Setpoint reset:
 - 1) If chiller is operating only to maintain secondary chilled water temperature setpoint, then no reset is required. Maintain setpoint at initial condition.
 - 2) If chiller is operating to provide dehumidification, reset the leaving water temperature upwards in one degree

- increments every 10 minutes (adj.) as call for dehumidification is reduced.
- 3) If chiller is operating to provide cooling at an air handling unit coil, raise setpoint at 1 degree F increments every 10 minutes (adj.) as call for cooling is reduced.
 - 4) Setpoint shall, in all cases, be as low as required for the most demanding of the three sequences above.
8. Variable volume secondary chilled water loop, variable speed secondary pumps (lead/lag), and differential pressure station. Flowrate is reduced as two-way valves in system close off.
- a. Pump selection:
 - 1) The two pumps operate in a lead/lag fashion and are controlled by the BMS based on the loop differential pressure.
 - 2) The BMS shall enable the VFD and provide speed reference to maintain system pressure.
 - 3) When an air handler is enabled the lead pump is commanded ON.
 - 4) If the lead pump does not proof ON (via VFD current output), the lag pump is commanded ON and the lead pump is commanded OFF - an alarm is generated.
 - 5) If the lag pump does not proof ON (via VFD current output), an alarm is generated. The enable command is maintained on to allow the system to run if the VFD clears.
 - 6) The BMS rotates the lead/lag pump assignment based on one of the following screen selectable conditions:
 - a) Manually, through a software switch
 - b) When the lead pump runtime exceeds 300 hours (adj.), the lag pump will become the lead pump.
 - c) With a schedule, as determined by user.
 - b. Secondary chilled water differential pressure control:
 - 1) The lead pump VFD speed is ramped using a PI algorithm to maintain the secondary loop differential pressure at 3 psi (adj.).
 - 2) If the lead pump VFD speed rises above 90% (adj.), the lag pump is enabled and its speed is set to match the lead pump speed. The two pumps continue to operate in unison to maintain the differential pressure setpoint.
 - 3) If the speed of the lead and lag pump falls to 30% (adj.), the lag pump is disabled and the lead pump operates alone.
 - 4) The BMS incorporates adjustable pump enable/disable delay timers to prevent short cycling. These timers are tuned during the startup and commissioning process.
 - 5) The VFD minimum speed shall not be set below 30%.
9. 3-way valve: Mixes return water with supply water to supply chilled beams with 57 degree F (adj.) water to prevent chilled beams from condensing. The temperature is adjusted as needed to compensate for changing dewpoint.
- a. Secondary chilled water supply temperature control
 - 1) Modulate 3-way valve to mix secondary return water with supply water and maintain secondary supply water setpoint at sensor.
 - b. Secondary chilled water supply temperature reset
 - 1) Upon startup of system initial setpoint shall be 57 degrees F (adj.)

10. Waterside economizer loop with dry cooler DC-1 and variable speed pump. Pump diverts return water through the dry cooler via a tertiary loop. Pump modulates and dry cooler fans sequence as required.
 - a. When secondary chilled water pump is running and secondary return water temperature is at least 4 degrees F (adj.) greater than OAT, enable pump and dry cooler DC-1.
 - b. Stage pump and fans as follows to maintain return water temperature equal to the supply water setpoint:
 - 1) Enable pump at full speed initially.
 - 2) Enable DC-1 lead fan.
 - 3) If setpoint cannot be maintained, stage on other DC-1 fans. As load is reduced cycle lag fan off and reduce pump speed to maintain setpoint. Do not reduce temperature lower than setpoint to prevent condensing.
 - c. Fan selection
 - 1) If the lead fan does not proof ON (via current output), the lag fan is commanded ON and the lead fan is commanded OFF - an alarm is generated.
 - 2) If the lag fan does not proof ON (via current output), an alarm is generated. The enable command is maintained on to allow the fan to run if the alarm clears.
 - 3) The BMS rotates the lead/lag fan assignment based on one of the following screen selectable conditions:
 - a) Manually, through a software switch.
 - b) When the lead fan runtime exceeds 300 hours (adj.), the lag fan will become the lead fan.
 - c) With a schedule, as determined by user.
11. Chilled beam chilled water loop: variable speed pumps (lead and lag) circulate water to the chilled beams to cool the building.
 - a. Pump selection:
 - 1) The two pumps operate in a lead/lag fashion and are controlled by the BMS based on the loop differential pressure. The lead pump is enabled by the BMS whenever an air handling unit is running and there is a call for cooling.
 - 2) The BMS shall enable the VFD and provide speed reference to maintain system pressure.
 - 3) When an air handler is enabled the lead pump is commanded ON.
 - 4) If the lead pump does not proof ON (via VFD current output), the lag pump is commanded ON and the lead pump is commanded OFF - an alarm is generated.
 - 5) If the lag pump does not proof ON (via VFD current output), an alarm is generated. The enable command is maintained on to allow the system to run if the VFD clears.
 - 6) The BMS rotates the lead/lag pump assignment based on one of the following screen selectable conditions:
 - a) Manually, through a software switch
 - b) When the lead pump runtime exceeds 300 hours (adj.), the lag pump will become the lead pump.
 - c) With a schedule, as determined by user.
 - b. Coil control valve - see chilled beam sequence.
12. Input/Output Point Monitoring Summary:
 - a. As a minimum, the following points and features are to be monitored and alarmed. Control Contractor shall add additional

points necessary to accomplish sequence of operation and interface with other control equipment.

1) Inputs:

- a) Chiller run status (Chiller Bacnet communications)
- b) Chilled water primary pump status (VFD Communications)
- c) Chilled water primary pump status (VFD Communications)
- d) Chilled water secondary pump status (VFD Communications)
- e) Chilled water secondary pump status (VFD Communications)
- f) Chilled water tertiary pump status (VFD Communications)
- g) Chilled water tertiary pump status (VFD Communications)
- h) Dry cooler pump status (VFD Communications)
- i) Dry cooler fan 1 status (BI)
- j) Dry cooler fan 2 status (BI)
- k) Dry cooler fan 4 status (BI)
- l) Dry cooler fan 4 status (BI)
- m) Dry cooler fan 5 status (BI)
- n) Chiller chilled water leaving temperature (AI)
- o) Chiller chilled water return temperature (AI)
- p) Secondary chilled water temperature (AI)
- q) Tertiary chilled water temperature (AI)
- r) Primary chilled water differential pressure (AI)
- s) Secondary chilled water differential pressure (AI)
- t) Tertiary chilled water differential pressure (AI)
- u) Chilled water system pressure at makeup (BI).

2) Outputs:

- a) Chilled Water primary pump start/stop (AO) or (VFD Communications)
- b) Chilled Water primary pump start/stop (AO) or (VFD Communications)
- c) Chilled Water secondary pump start/stop (AO) or (VFD Communications)
- d) Chilled Water secondary pump start/stop (AO) or (VFD Communications)
- e) Chilled Water tertiary pump start/stop (AO) or (VFD Communications)
- f) Chilled Water tertiary pump start/stop (AO) or (VFD Communications)
- g) Dry cooler pump start/stop (AO) or (VFD Communications)
- h) Dry cooler fan 1 stop/start (BO)
- i) Dry cooler fan 2 stop/start (BO)
- j) Dry cooler fan 3 stop/start (BO)
- k) Dry cooler fan 4 stop/start (BO)
- l) Dry cooler fan 5 stop/start (BO)
- m) Chilled Water primary pump speed (AO) or (VFD Communications)
- n) Chilled Water primary pump speed (AO) or (VFD Communications)
- o) Chilled Water secondary pump speed (AO) or (VFD Communications)
- p) Chilled Water secondary pump speed (AO) or (VFD Communications)
- q) Chilled Water tertiary pump speed (AO) or (VFD Communications)
- r) Chilled Water tertiary pump speed (AO) or (VFD Communications)
- s) Chiller chilled water supply set point (Chiller Bacnet communications)

- t) Chiller control panel enable/disable (Chiller Bacnet communications)
- 3) General Alarms:
 - a) Chiller control panel general alarm (annunciated).
 - b) Chiller control panel communication failure.
 - c) Chiller failure (annunciated).
 - d) Primary chilled water pump failure (annunciated).
 - e) Secondary chilled water pump failure (annunciated).
 - f) Tertiary chilled water pump failure (annunciated).
 - g) Glycol makeup unit (GMU-1) alarm.
 - h) Chiller chilled water supply temperature high/low.
 - i) Alarm at excess of 10% above or below setpoint.
 - j) Any unscheduled chilled water system shut-down.

G. DOMESTIC WATER HEATING (POTABLE AND NON-POTABLE)

1. Domestic (potable) water is pre-heated using rooftop solar panels when solar energy is available. Pre-heated water is supplied to steam-to-water heat exchangers which boost the temperature as required to supply 140 deg F (adjustable) water. Steam-to-water heat exchangers receive low pressure steam from the central plant and generate domestic hot water meeting setpoint from BMS. Steam control valve receives signal from BMS.
2. Solar Water Circulating Pumps SCP-1A/1B and SCP-2: Solar collector pumps SCP-1A/B operate in a lead/lag fashion. SCP-1A/B and SCP-2 pumps operate simultaneously in series to transfer heat from solar collectors to the solar heated water storage tank, via an insertion type heat exchanger, with On/Off control to maintain storage tank temperature setpoint. Pumps are controlled by local H-O-A switch, with Auto control as follows:
 - a. Start SCP-1A/B, SCP-2 when storage tank temperature is below 130 deg F (adjustable), and solar collector plate temperature is 10 deg F or greater than storage tank temperature.
 - b. Stop SCP-1A/B, SCP-2 when storage tank temperature is 140 deg F (adjustable).
 - c. Stop SCP-1A/B, SCP-2 when solar collector plate temperature is 2 deg F or less than storage tank temperature.
 - d. Stop SCP-1A/B, SCP-2 if Level Switch 1 indicates low water condition in drain-back storage tank. Level Switch 1 shall be directly wired to pump control circuit and shall be capable of stopping pumps without signal from BAS.
 - e. Stop SCP-1A/B, SCP-2 if pressure on suction side of SCP-1 is less than 2 psi (adj.).
 - f. Establish PID loop control to stabilize pump operation and to avoid erratic fill/drain cycle in solar collectors.
 - g. Initiate alarm for "Manual Fill Required" when water level in drain-back storage tank falls to Level Switch 2.
3. Domestic Hot Water Recirculation Pump DP-1, DP-2, DP-3: DP-3 is a standalone pump and operates subject to the BAS schedule. DP-1 and DP-2 pumps operate in a lead-lag arrangement subject to the BAS schedule. Lead pump shall activate as required to maintain the domestic hot water return temperature setpoint. Lead pump to alternate once per month. If lead pump fails for 15 seconds, as sensed by a pump motor current transformer switch, lag pump shall start and an alarm is sent to the BAS. Pump operates with On/Off control to maintain domestic hot water return temperature setpoint.

Pump is controlled by local H-O-A switch, with Auto control as follows:

- a. Monitor hot water return with immersion temperature sensor in domestic hot water recirculation piping located approximately 2 feet upstream from DP-1, DP-2, DP-3.
 - b. Start DP-1, DP-2, DP-3 when hot water return temperature is 140 deg F (adjustable) or lower.
 - c. Stop DP-1, DP-2, DP-3 when hot water return temperature is 145 deg F (adjustable) or higher.
4. Input/Output Point Monitoring Summary:
- a. As a minimum, the following points and features are to be monitored and alarmed. The Control Contractor shall add any additional points necessary to accomplish the sequence of operation and interface with other control equipment.
 - b. Inputs:
 - 1) Domestic Hot Water Supply Temperature (potable), leaving heat exchanger HX-5 (AI).
 - 2) Domestic Hot Water Supply Temperature (potable), leaving heat exchangers HX-1&2 (AI).
 - 3) Domestic Hot Water Supply Temperature (non-potable), leaving heat exchanger (AI).
 - 4) Domestic Hot Water Return Temperature (potable) (AI).
 - 5) Domestic Hot Water Return Temperature (non-potable) (AI).
 - 6) Pressure at suction side of SCP-1A/B (AI).
 - 7) Solar Heated Water Storage Tank Temperature (AI).
 - 8) Solar Collector Temperature, immersion-type acceptable (AI).
 - 9) Solar Heated Water Return Temperature to drain-back tank (AI).
 - 10) Solar Drain-Back Storage Tank Level Switch 1 (BI).
 - 11) Solar Drain-Back Storage Tank Level Switch 2 (BI).
 - 12) Pump operational status for DP-1, DP-2 based on current transformer switch (CT), (BI).
 - 13) Pump operational status for SCP-1A/B, SCP-2, based on current transformer switch (CT), (BI).
 - 14) Heat exchanger HX-3 steam valve position feedback, 1/3 capacity (AI).
 - 15) Heat exchanger HX-4 steam valve position feedback, 1/3 capacity (AI).
 - 16) Heat exchanger HX-6 steam valve position feedback, 1/3 capacity (AI).
 - 17) Heat exchanger HX-3 steam valve position feedback, 2/3 capacity (AI).
 - 18) Heat exchanger HX-4 steam valve position feedback, 2/3 capacity (AI).
 - 19) Heat exchanger HX-6 steam valve position feedback, 2/3 capacity (AI).
 - c. Outputs:
 - 1) Domestic Hot Water Return Temperature setpoint (AO).
 - 2) DP-1, DP-2, DP-3 start/stop (BO).
 - 3) SCP-1A/B, SCP-2 start/stop (BO).
 - 4) Heat exchanger HX-3 steam control valve position, 1/3 capacity (AO).
 - 5) Heat exchanger HX-4 steam control valve position, 1/3 capacity (AO).
 - 6) Heat exchanger HX-6 steam control valve position, 1/3

- capacity (AO).
- 7) Heat exchanger HX-3 steam control valve position, 2/3 capacity (AO).
- 8) Heat exchanger HX-4 steam control valve position, 2/3 capacity (AO).
- 9) Heat exchanger HX-6 steam control valve position, 2/3 capacity (AO).
- d. Alarms:
 - 1) Low pressure at suction side of SCP-1A/B.
 - 2) Unscheduled pump shutdown for DP-1, DP-2, DP-3, SCP-1A/B, SCP-2.
 - 3) Pump failure for DP-1, DP-2, DP-3, SCP-1A/B, SCP-2.
 - 4) Solar heated storage tank temperature at 145 deg F or higher.
 - 5) Manual fill required at drain back tank, initiated by Level Switch 2.
 - 6) Low water pump shutoff, initiated by drain-back tank Level Switch 1.
 - 7) High temperature alarm for domestic hot water leaving heat exchangers.
 - 8) Low temperature alarm for domestic hot water leaving heat exchangers.

H. MISCELLANEOUS

- 1. Sewage pump level monitoring - Receive level alarm from control panel of SP-2/3.
- 2. Sump pump level monitoring - Receive level alarm from control panel of SP-1.
- 3. Smart meter monitoring for HVAC chilled and heating hot water systems, meter tags WM-1 and WM-2.
- 4. Domestic water booster pump monitoring:
 - a. Automatic control through Booster Pump BP-1 manufacturer's control panel. Connect BAS to contactor in panel for remote monitoring of general alarms.

END OF SECTION