

SECTION 23 09 23  
DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 - GENERAL

1.1 DESCRIPTION

A. Provide direct-digital control system(s) as indicated on the project documents, interoperability tables, drawings and as described in these specifications. Include a complete and working direct-digital control system. Include all existing system and graphics expansion/updates, 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 a fully integrated high-speed, peer-to-peer network of interconnected DDC controllers (on emergency power), connected to the existing Campus, and Engineering Control Center. Using the existing VA Hospital IT network, provide a secure, software based remote access via PC anywhere to the control system graphics and ability to change adjustable setpoints with the proper password.
2. The direct-digital control system(s) shall be 100% compatible with the existing Johnson Controls DDC system. All new or existing workstations, controllers, devices and components shall be accessible using a secure, software based interface and the existing workstation shall be capable of communication using the ASHRAE Standard 135 BACnet communications protocol.
  - 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. Provide a complete DDC Control system for all equipment and component installed as a part of the scope of this project including air handling units, return fans, condensate pumps, heat exchangers, pumps, chillers, air terminals, terminal units, fans, exhaust fans, humidifiers, smaller air conditioning systems, dampers, variable speed drives, low voltage system interface, generators, miscellaneous alarm management, etc. Provide all required controllers, valves,

dampers, actuators, wiring, etc. Provide most current version of software and equipment for new control system. Provide web based interface. Provide licensing for all workstations. Provide all required software, programming and startup. Link new control system with existing control system. Update and repair existing control system as needed to interface with new control system. Coordinate all required data drops for new control system. As a minimum, provide data drops in both mechanical rooms and the Telcom rooms. The system shall utilize open architecture that shall support systems and equipment from multiple vendors. Provide and install all required wiring, conduit, fiber, etc. required to interface with the existing DDC system. Provide low voltage actuators powered through the DDC system or provide and install all required electrical circuiting, conduit, breakers, etc. needed for actuators. Entire DDC system shall be UL864/UUKL listed for smoke control applications. Interface with Fire Detection and Alarm System as needed to perform required sequences. Provide and install power wiring and conduits from spare 20 amp circuit breakers in nearest emergency equipment branch power panel. Provide and install local UPS to assure uninterrupted DDC system operation during switchover between normal to emergency power.

4. 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.
5. 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.

6. The control system shall accommodate an unlimited number of ECC's simultaneously, and the access to the system should be limited only by operator password.
  7. Send all alarms to the Bausch Security System at the Security office and the DDC terminal in the Boiler Room.
- 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. Control dampers (not unit mounted).
  3. Flow switches.
  4. Current sensors.
  5. Flow meters.
  6. Sensor wells and sockets in piping.
  7. 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. Terminal units' velocity sensors.
4. Unitary HVAC equipment (air conditioning units, split systems, packaged pumping stations, controls. Provide Modbus or BACnet Gateway. These include:
  - a. Discharge temperature control.
  - b. Economizer control.
  - c. Flowrate control.
  - d. Setpoint reset.
  - e. Time of day indexing.
  - f. Status alarm.
5. Variable frequency drives. These controls, if not native BACnet, will require a BACnet Gateway.
6. The following systems shall have limited monitoring (as individually noted below) from the existing ECC:
  - a. Emergency generators: status alarms.
  - b. Domestic water heating systems: low temperature, high temperature and status alarms.
  - c. Stormwater removal pumps: status alarm.
  - d. Sanitary sewage pumps: status alarm.

E. 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

Work/Item/System	Furnish	Install	Low Voltage Wiring	Line Power
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
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/Smoke Dampers	23	23	28 31 00	28 31 00
Smoke Dampers	23	23	28 31 00	28 31 00
VFDs	23 09 23	26	23 09 23	26
Data Room A/C Unit field-mounted controls	23	23	16	26
Control system interface with Data Room A/C controls	23 09 23	23 09 23	23 09 23	26
Data Room A/C unit controls interface with control system	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
Fire-fighter's smoke control station (FSCS)	28	28	28	28
Fan Coil Unit controls (not furnished with equipment)	23 09 23	23 09 23	23 09 23	26

Work/Item/System	Furnish	Install	Low Voltage Wiring	Line Power
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

F. This facility's existing direct-digital control system is manufactured by Johnson Controls, and its ECC is located at Building #1. 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. The combined system shall operate and function as one complete system including one database of control point objects and global control logic capabilities. All installed components and parts need to be compatible with the facilities existing control system. 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.

2. Responsibility Table:

Item/Task	Section 23 09 23 contractor	Control system integrator	VA
ECC expansion		X	
ECC programming		X	
Devices, controllers, control panels and equipment	X	X	
Point addressing: all hardware and software points including setpoint, calculated point, data point(analog/binary), and reset schedule point	X	X	
Point mapping	X	X	
Network Programming	X	X	
ECC Graphics	X	X	
Controller programming and sequences	X	X	
Integrity of LAN communications			X
Electrical wiring	X	X	
Operator system training	X	X	
LAN connections to devices	X		
LAN connections to ECC	X	X	

IP addresses			X
Overall system verification	X	X	
Controller and LAN system verification	X		X

G. Unitary standalone systems including unit heaters, cabinet unit heaters, and similar units for control of room environment conditions are to be equipped with DDC controls furnished and installed by Control Contractor and field mounted. Refer to equipment specifications and as indicated in project documents. Application of standalone unitary controls is limited to those systems wherein remote monitoring, alarm and start-up are not necessary. Examples of such systems include:

1. Light-switch-operated toilet exhaust.
2. Mechanical or electrical room heating and ventilation.

## 1.2 RELATED WORK

- A. Section 23 73 00, Indoor Central-Station Air-Handling Units.
- B. Section 23 81 23, Computer-Room Air-Conditioners.
- C. Section 26 05 11, Requirements for Electrical Installations.
- D. Section 26 05 21, Low-Voltage Electrical Power Conductors and Cables (600 Volts and Below).
- E. Section 26 05 26, Grounding and Bonding for Electrical Systems.
- F. Section 26 05 33, Raceway and Boxes for Electrical Systems.
- G. Section 26 09 23, Lighting Controls.
- ~~H. Section 26 22 21, Specialty Transformers.~~
- ~~I. Section 26 27 26, Wiring Devices.~~
- ~~J. Section 26 29 11, Motor Starters.~~
- ~~K. Section 27 15 00, Communications Horizontal Cabling~~
- ~~L. Section 28 31 00, Fire Detection and Alarm.~~
- L. Section 01 91 00, General Commissioning Requirements.**

## 1.2 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. ARCNET: ANSI/ATA 878.1 - Attached Resource Computer Network. ARCNET is a deterministic LAN technology; meaning it's possible to determine the maximum delay before a device is able to transmit a message.
- C. Analog: A continuously varying signal value (e.g., temperature, current, velocity etc).

- D. 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.
- E. 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.
- F. BACnet Internetwork: Two or more BACnet networks connected with routers. The two networks may sue different LAN technologies.
- G. 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.
- H. BACnet Segment: One or more physical segments of BACnet devices on a BACnet network, connected at the physical layer by repeaters.
- I. 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.
- J. 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.
- K. BACnet Testing Laboratories (BTL). The organization responsible for testing products for compliance with the BACnet standard, operated under the direction of BACnet International.
- L. 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).
- M. 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.
- N. 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.



- O. Bus Topology: A network topology that physically interconnects workstations and network devices in parallel on a network segment.
- P. 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
- Q. 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).
- R. Device: a control system component that contains a BACnet Device Object and uses BACnet to communicate with other devices.
- S. 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.
- T. 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.
- U. 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.
- V. 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.
- W. 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.

- X. 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.
- Y. DXF: An AutoCAD 2-D graphics file format. Many CAD systems import and export the DXF format for graphics interchange.
- Z. 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.
- AA. 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.
- BB. 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.
- CC. Ethernet: A trademark for a system for exchanging messages between computers on a local area network using coaxial, fiber optic, or twisted-pair cables.
- DD. Firmware: Firmware is software programmed into read only memory (ROM) chips. Software may not be changed without physically altering the chip.
- EE. 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.
- FF. GIF: Abbreviation of Graphic interchange format.
- GG. 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.
- HH. Graphic Sequence of Operation: It is a graphical representation of the sequence of operation, showing all inputs and output logical blocks.

- II. 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.
- JJ. 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.
- KK. JPEG: A standardized image compression mechanism stands for Joint Photographic Experts Group, the original name of the committee that wrote the standard.
- LL. Local Area Network (LAN): A communication bus that interconnects operator workstation and digital controllers for peer-to-peer communications, sharing resources and exchanging information.
- MM. Network Repeater: A device that receives data packet from one network and rebroadcasts to another network. No routing information is added to the protocol.
- NN. MS/TP: Master-slave/token-passing (ISO/IEC 8802, Part 3). It is not an acceptable LAN option for VA health-care facilities. It uses twisted-pair wiring for relatively low speed and low cost communication.
- OO. 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.
- PP. 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.
- QQ. Object: The concept of organizing BACnet information into standard components with various associated properties. Examples include analog input objects and binary output objects.

- RR. Object Identifier: An object property used to identify the object, including object type and instance. Object Identifiers must be unique within a device.
- SS. 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.
- TT. Operating system (OS): Software, which controls the execution of computer application programs.
- UU. 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.
- VV. Peripheral: Different components that make the control system function as one unit. Peripherals include monitor, printer, and I/O unit.
- WW. 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.
- XX. PICS: Protocol Implementation Conformance Statement, describing the BACnet capabilities of a device. All BACnet devices have published PICS.
- YY. PID: Proportional, integral, and derivative control, used to control modulating equipment to maintain a setpoint.
- ZZ. Repeater: A network component that connects two or more physical segments at the physical layer.
- AAA. 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.
- BBB. Sensors: Devices measuring state points or flows, which are then transmitted back to the DDC system.
- CCC. 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. Provide one graphic for each piece of equipment.
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	$\pm 0.5^{\circ}\text{C}$ ( $\pm 1^{\circ}\text{F}$ )
Ducted air temperature	$\pm 0.5^{\circ}\text{C}$ [ $\pm 1^{\circ}\text{F}$ ]
Outdoor air temperature	$\pm 1.0^{\circ}\text{C}$ [ $\pm 2^{\circ}\text{F}$ ]
Dew Point	$\pm 1.5^{\circ}\text{C}$ [ $\pm 3^{\circ}\text{F}$ ]
Water temperature	$\pm 0.5^{\circ}\text{C}$ [ $\pm 1^{\circ}\text{F}$ ]
Relative humidity	$\pm 2\%$ RH
Air flow (terminal)	$\pm 10\%$ of reading
Air flow (measuring stations)	$\pm 5\%$ of reading
Carbon Dioxide ( $\text{CO}_2$ )	$\pm 50$ ppm
Air pressure (ducts)	$\pm 25$ Pa [ $\pm 0.1$ "w.c.]
Air pressure (space)	$\pm 0.3$ Pa [ $\pm 0.001$ "w.c.]
Electrical Power	$\pm 0.5\%$ of reading

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

Controlled Variable	Control Accuracy	Range of Medium
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	$\pm 10$ kPa ( $\pm 1.5$ psi)	0-1 MPa (1-150 psi)
Fluid Pressure	$\pm 250$ Pa ( $\pm 1.0$ 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 components indicated on the drawings and in the specifications.

#### **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. The on-line support service shall allow the Controls supplier to connect via (through password-limited access) VPN through the internet monitor and control the facility's building automation system. This remote connection to the facility shall be within two (2) hours of the time that the problem is reported by VA Facilities personnel to the controls contractor responsible for the system. This coverage shall be extended to include normal business hours, after business hours, weekend and holidays. If the problem cannot be resolved with on-line support services, the Controls supplier shall dispatch the qualified personnel to the job site to resolve the problem within 24 hours after the problem is reported.
- D. 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.
  14. Points list matrix.
- C. Product Certificates: Compliance with Article, QUALITY ASSURANCE.
- D. Licenses: Provide a minimum of four (4) 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 C.O.T.R. 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 digitally record audio and video 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 existing and new 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 135-08.....BACNET Building Automation and Control Networks
- C. American Society of Mechanical Engineers (ASME):  
B16.18-05.....Cast Copper Alloy Solder Joint Pressure Fittings.  
B16.22-05.....Wrought Copper and Copper Alloy Solder Joint Pressure Fittings.
- D. American Society of Testing Materials (ASTM):  
B32-04.....Standard Specification for Solder Metal  
B88-03.....Standard Specifications for Seamless Copper Water Tube  
B88M-05.....Standard Specification for Seamless Copper Water Tube (Metric)  
B280-03.....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):

802.3-05.....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):

70-08.....National Electric Code  
90A-09.....Standard for Installation of Air-Conditioning  
and Ventilation Systems

H. Underwriter Laboratories Inc (UL):

94-06.....Tests for Flammability of Plastic Materials for  
Parts and Devices and Appliances  
294-05.....Access Control System Units  
486A/486B-04-.....Wire Connectors  
555S-06.....Standard for Smoke Dampers  
916-07.....Energy Management Equipment  
1076-05.....Proprietary 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 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 needed to service all new systems and components, the following:
  - a. The existing 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. They may also utilize digital wireless technologies as appropriate to the application and if approved by the VA.
  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) as needed 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 existing 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 such as Microsoft SQL Server and Microsoft Data Engine (MSDE) or approved equal.

**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.
  2. The ARCNET data link / physical protocol may be used in new BACnet sub-networks in VA non-healthcare and non-lab (i.e., business and cemetery) facilities.
  3. The MS/TP data link / physical layer protocol is not acceptable to the VA in any new BACnet network or sub-network in its healthcare or lab facilities.
- B. Each controller shall have a communication port for connection to an operator interface.
- C. 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.
- D. 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.
- E. 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 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.

## 2.5 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. 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.
  9. Memory. The controller shall maintain all BIOS and programming information in the event of a power loss for at least 72 hours.
  10. 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 reside on an ARCNET network using the ISO 8802-2 Data Link/Physical layer protocol for its communications.
  - c. 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. Alarms shall be monitored at the security station through the Bausch Security System and at the Boiler Room. 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, cell phones, 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.

## **2.6 SENSORS (AIR, WATER AND STEAM)**

- 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 or Resistance Temperature Device (RTD) with an integral transmitter type.
  - 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 override switch. Match room thermostats. Provide a tooled-access cover. Provide 5 degree deadband (70°F - 75°F).
  - 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.
  - 2) Psychiatric patient room sensor: sensor shall be flush with wall, shall not include an override switch, numerical temperature display on sensor cover, shall not include a communication port and shall not allow in-space User set-point adjustment. Setpoint adjustment shall be only through the ECC or through the DDC system's diagnostic device/laptop. Provide a stainless steel coverplate with an insulated back and security screws.
- 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.
- 2. Humidity Sensors: Bulk polymer sensing element type.
  - a. Duct and room sensors shall have a sensing range of 20 to 80 percent with accuracy of  $\pm 2$  to  $\pm 5$  percent RH, including hysteresis, linearity, and repeatability.
  - b. Outdoor humidity sensors shall be furnished with element guard and mounting plate and have a sensing range of 0 to 100 percent RH.
  - c. 4-20 ma continuous output signal.
- 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. 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. Analog Current Sensors with 4 to 20mA or 0-10 VDC/0-5VDC outputs shall be utilized for Fan & Pump motor operating status and be capable of measuring change in current load due to thrown belts.

## 2.7 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 plenum-rated insulated conductors as specified in Section 26 05 21.

C. Copper digital communication cable between the ECC and the network 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. Copper digital communication RS-485 cable for field controllers shall be 2 wire, Twisted Shielded Pair, Plenum Rated Low Capacitance (12 pF or lower).

D. Optical digital communication fiber, if used, shall be 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.

## **2.8 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: 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 gage).
- D. Smoke Dampers and Combination Fire/Smoke Dampers: Dampers and operators are specified in Section 23 31 00, HVAC DUCTS AND CASINGS. Control of these dampers is specified under this Section.
- 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. Brass or bronze seats except for valves controlling media above 100 degrees C (210 degrees F), which shall have stainless steel seats.
  4. 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.
  5. 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).
- 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 closeoff torque.

a. Minimum valve closeoff 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 closeoff torque.

a. VAV Box actuator shall be actuated by an integral actuator/DDC controller which 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.
4. All actuators shall be low voltage and all power requirements shall be provided through the DDC system.

## **2.9 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 -- Electronic Thermal Type:

1. Air Flow Sensor Probe:

- a. Each air flow sensor shall contain two individual thermal sensing elements. One element shall determine the velocity of the air stream while the other element shall compensate for changes in temperature. Each thermal flow sensor and its associated control circuit and signal conditioning circuit shall be factory calibrated and be interchangeable to allow replacement of a sensor without recalibration of the entire flow station. The sensor in the array shall be located at the center of equal area segment of the duct and the number of sensors shall be adequate to accommodate the expected velocity profile and variation in flow and temperature. The airflow station shall be of the insertion type in which sensor support structures are inserted from the outside of the ducts to make up the complete electronic velocity array.
- b. Thermal flow sensor shall be constructed of hermetically sealed thermistors or nickel chromium or reference grade platinum wire, wound over an epoxy, stainless steel or ceramic mandrel and coated with a material suitable for the conditions to be encountered. Each dual sensor shall be mounted in an extruded aluminum alloy strut.

2. Air Flow Sensor Grid Array:

- a. Each sensor grid shall consist of a lattice network of temperature sensors and linear integral controllers (ICs) situated inside an aluminum casing suitable for mounting in a duct. Each sensor shall be mounted within a strut facing downstream of the airflow and located so that it is protected on the upstream side. All wiring shall be encased (out of the air stream) to protect against mechanical damage.
- b. The casing shall be made of welded aluminum of sufficient strength to prevent structural bending and bowing. Steel or iron composite shall not be acceptable in the casing material.
- c. Pressure drop through the flow station shall not exceed 4 Pascal (0.015" W.G.) at 1,000 meter per minute (3,000 FPM).

3. Electronics Panel:

- a. Electronics Panel shall consist of a surface mounted enclosure complete with solid-state microprocessor and software.
  - b. Electronics Panel shall be A/C powered 24 VAC and shall have the capability to transmit signals of 0-5 VDC, 0-10 VCD or 4-20 ma for use in control of the HVAC Systems. The electronic panel shall have the capability to accept user defined scaling parameters for all output signals.
  - c. Electronics Panel shall have the capability to digitally display airflow in CFM and temperature in degrees F. The displays shall be provided as an integral part of the electronics panel. The electronic panel shall have the capability to totalize the output flow in CFM for two or more systems, as required. A single output signal may be provided which will equal the sum of the systems totalized. Output signals shall be provided for temperature and airflow. Provide remote mounted air flow or temperature displays where indicated on the plans.
  - d. Electronics Panel shall have the following:
    - 1) Minimum of 12-bit A/D conversion.
    - 2) Field adjustable digital primary output offset and gain.
    - 3) Airflow analog output scaling of 100 to 10,000 FPM.
    - 4) Temperature analog output scaling from -45°C to 70°C (-50°F to 160°F).
    - 5) Analog output resolution (full scale output) of 0.025%.
  - e. All readings shall be in I.P. units.
- C. Static Pressure Measuring Station: 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.

#### **2.10 EXTRA MATERIALS**

- A. Provide one replacement mechanism for each unique damper motor, valve motor, relay, temperature sensor, humidity sensor, flow meter, dry contact pressure sensor, current sensor, smoke detector.
- B. Extra materials shall match installed products and packaged with protective coverings for storage and identification.

### **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 Resident Engineer for resolution before proceeding for installation.
  2. Work Coordination: GENERAL CONDITIONS.
  3. Install equipment, piping, wiring /conduit parallel to or at right angles to building lines.
  4. Install all equipment and piping in readily accessible locations. Do not run tubing and conduit concealed under insulation or inside ducts.
  5. Mount control devices, tubing and conduit located on ducts and apparatus with external insulation on standoff support to avoid interference with insulation.
  6. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.

7. Run tubing and wire connecting devices on or in control cabinets parallel with the sides of the cabinet neatly racked to permit tracing.

8. Install equipment level and plum.

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 (unless otherwise noted).
    - e. Mount sensors rigidly and adequately for the environment within which the sensor operates. Separate extended-bulb sensors from 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.

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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, outdoor humidity, 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 air handling unit, fan, terminal unit, 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. The following witnessed demonstrations of field control equipment shall be included:
  - a. Observe HVAC systems in shut down condition. Check dampers and valves for normal position.
  - b. Test application software for its ability to communicate with digital controllers, operator workstation, and uploading and downloading of control programs.

- c. Demonstrate the software ability to edit the control program off-line.
- d. Demonstrate reporting of alarm conditions for each alarm and ensure that these alarms are received at the assigned location, including operator workstations.
- e. Demonstrate ability of software program to function for the intended applications-trend reports, change in status etc.
- f. Demonstrate via graphed trends to show the sequence of operation is executed in correct manner, and that the HVAC systems operate properly through the complete sequence of operation, e.g., seasonal change, occupied/unoccupied mode, and warm-up condition.
- g. Demonstrate hardware interlocks and safeties functions, and that the control systems perform the correct sequence of operation after power loss and resumption of power loss.
- h. Demonstrate access to all building controls components through the existing ECC graphics interface.
- i. Prepare and deliver to the VA graphed trends of all control loops to demonstrate that each control loop is stable and the set points are maintained.
- j. Demonstrate that each control loop responds to set point adjustment and stabilizes within one (1) minute. Control loop trend data shall be instantaneous and the time between data points shall not be greater than one (1) minute.

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