

# MEDICAL CENTER SPECIAL REQUIREMENTS APPENDIX A – INSTRUMENTATION AND CONTROL FOR HVAC

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*The Special Requirements indicated in this appendix shall be incorporated in all Design Documents for Medical Center Projects. These Special Requirements consist of exceptions, revisions or additions to the base Building Design Standards.*

## PART 1- GENERAL

### 1.01 SCOPE

- A. Furnish and install a complete native BACnet DDC Building Automation System (BAS) as manufactured by Delta Controls, Inc. to automatically control the operation of the new HVAC system. The new Building Automation System shall fully integrate into the existing district wide native BACnet Delta Controls virtual private network (VPN). The required integration shall include the creation of custom graphics and the compilation and display of all devices and objects on the existing Delta Controls Operator Workstation (OWS) and Webserver. All graphic displays will reside on the existing Delta Controls OWS and be modified accordingly. In addition, the system shall perform the said integration through the use of BACnet/IP communications (Annex J only). BACnet over Ethernet will not be supported for district wide communications. All integration work shall be performed in cooperation with Delta Controls, Inc. or its local representative. Failure to mention any specific item or device does not relieve the Contractor of the responsibility for installing or integrating such device/peripheral in order to comply with the intent of the Drawings or this Specification.
- B. Proposed Equals shall be proposed as outlined in the Instructions to Bidders, Article 2.5, and as detailed below and must submit product for testing purposes prior to bid. To obtain approval to use unspecified products as 'approved equals', Bidders shall submit written requests to the Associate at least ten (10) working days before the bid date. Requests received after this time will not be considered. Requests shall clearly describe the system for which approval is asked, including all data necessary to demonstrate that it meets all performance requirements of the specifications. This data shall include but is not limited to, Protocol Implementation Conformance Statements, Device Profile listings, BIBB Summaries and Read/Write documentation (all similar to what is listed under this specification). If the proposed equal is found to be acceptable, an addendum will be issued, as outlined in the Instructions to Bidders, Article 2.5, to all contractors on record. Submitted data shall be organized, tabulated, and annotated as follows:
  1. Overall table of contents
  2. Individual table of contents for each section
  3. Tabulated list of included hardware and software (differentiated from available-but-not-included hardware and software)
  4. Tabulated list of conformance to each paragraph of this specification, listing any exceptions thereto
  5. Specific description of hardware, firmware, and software as proposed
  6. Campus-wide Ethernet network diagram applicable to this project
  7. Auto-dial/auto-answer communications network

8. Building-wide peer-to-peer Building Controller network diagram
9. Advanced Application Controller local area network diagram
10. Detailed description of graphic and display software characteristics
11. Detailed description of DDC control software characteristics
12. BACnet Compliance Documentation

C. Building Automation System (BAS) Contractor shall provide:

1. A fully integrated and fully programmable BACnet building automation system (BAS), UL listed (UL916 and UL864 If applicable), incorporating direct digital control (DDC) for energy management, equipment monitoring and control, as manufactured by Delta Controls. The use of algorithmic or canned programming controllers will not be permitted. A UL864 listing shall be required for all controllers that are utilized in a smoke control sequence and as necessary to meet or exceed all national and local codes. In addition, UL864 devices and non UL864 shall not be permitted on the same network segment unless the devices are separated with a UL864 Ethernet switch. All MS/TP network segments shall be consistent with its UL864 or non UL864 implementation. In other words, there shall not be UL864 product and non UL864 product on the same MS/TP network segment.
2. Necessary conduit, wiring, enclosures, and panels, for all DDC temperature control equipment and devices. Installation shall comply with applicable local and national codes.
3. All components and control devices necessary to provide a complete and operable DDC system as specified herein.
4. All final electrical connections to each stand-alone DDC Controller. Connect to 120VAC power as provided by the Division 26 contractor, to be terminated within 5 feet of the DDC Controller.
5. BAS Contractor shall be responsible for all electrical work associated with the BAS control system and as called for on the Drawings. This BAS control wiring shall be furnished and installed in accordance with the Electrical requirements as specified in Division 26, the National Electric Code, and all applicable local codes.
6. Surge transient protection shall be incorporated in design of system to protect electrical components in all Building Controllers, Advanced Application Controllers and operator's workstations. Provide an external protection device listed under UL 1449 with minimum clamping voltage of 130 VRMS and surge current capability of 22,500Amps for all custom fabricated control panels (all main system components (i.e, AHUs, Chillers, Boilers, etc.).
7. All 120V and low voltage electrical control wiring exposed throughout the building shall be run in conduit in accordance with the Electrical requirements as specified in Division 26, the National Electric Code, and all applicable local codes. All low voltage wiring that is concealed in accessible ceilings may be run in plenum rated cable per the National and Local Electrical codes.
8. All 24VAC power required for operation of the BAS shall be by the BAS Contractor and shall be limited to 100 VA per the aforementioned codes. Any 24VAC power link that exceeds the 100 VA rating must be installed in conduit per Division 26 and all applicable

codes, regardless of the nature of the installation.

9. BAS Contractor shall provide programming modifications necessary to fine tune sequences during commissioning and through the warranty period of system and for an additional 12 months, at no extra cost to The Ohio State Medical Center.

D. HVAC Contractor provides:

1. All wells and openings for water and air monitoring devices, temperature sensors, flow switches and alarms furnished by BAS Contractor.
2. Installation of all control valves as per the contract drawings. The temperature control contractor is not responsible for the incorrect installation of any domestic, hot or chilled water control valves.
3. Installation of all dampers and adjacent access doors for smoke; outdoor air, return air, exhaust air, and ventilation dampers.
4. All package unit control panels including but not limited to, factory boiler panels, factory chiller panels, refrigerant monitors and specialty interface modules required for BACnet compliance.

E. Electrical Contractor provides:

1. Electrical Contractor shall provide dedicated 120 volt, 20 amp circuits and circuit breakers from normal and/or emergency power panel for each DDC Controller. Run power circuit within 5 feet of equipment installed and connected by BAS Contractor.
2. Electrical contractor will also provide smoke detector and smoke damper interlock and power wiring for all life safety applications.

F. General Product Description:

1. The building automation system (BAS) shall integrate multiple building functions including equipment supervision and control, alarm management, energy management and historical data collection utilizing the BACnet protocol.
2. The building automation system shall consist of the following:
  - a. Stand-alone peer-to-peer Building Controllers with 32 bit processors, a minimum of 2 MB of flash memory and 10 bit A/D converters. Ethernet connectivity is required for all Building Controllers.
  - b. Stand-alone peer-to-peer Advanced Application Controllers with 32 bit processors, a minimum of 1 MB flash memory and 10-bit A/D converters. Ethernet or MS/TP connectivity will be permitted for all AACs.
  - c. Portable operator's terminal(s)
  - d. Provide seamless interconnection to the existing Delta Controls central graphic workstation, and build Delta Controls standard and HTML / ASP customized graphics displays in accordance with the existing formats.
3. The system shall be modular in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, Building Controllers, Advanced

Application Controllers, expansion modules and operator devices.

4. System architectural design shall eliminate dependence upon any single device for alarm reporting and control execution. Each DDC Controller shall operate independently by performing its own specified control, alarm management, operator I/O and data collection. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices. Alarm management and data collection that requires a single mechanism for user notification or viewing is strictly prohibited.
5. All Controllers shall be able to access any data from, or send control commands and alarm reports directly to, any other DDC Controller or combination of controllers on the network without dependence upon a central processing device (peer-to-peer). All Controllers shall also be able to send alarm reports to multiple operator workstations without dependence upon a central processing device.

## 1.02 RELATED WORK

### A. Specified elsewhere:

1. \_\_\_\_\_ - Sequence of Operation
2. \_\_\_\_\_ - Variable Speed Control
3. \_\_\_\_\_ - Basic Mechanical Requirements
4. \_\_\_\_\_ - Motors
5. \_\_\_\_\_ - HVAC Pumps
6. \_\_\_\_\_ - Boilers
7. \_\_\_\_\_ - Chillers
8. \_\_\_\_\_ - Cooling Tower
9. \_\_\_\_\_ - Terminal Heat Transfer Units
10. \_\_\_\_\_ - Air Handling Units
11. \_\_\_\_\_ - Testing, Adjusting and Balancing
12. \_\_\_\_\_ - Basic Electrical Materials and Methods
13. \_\_\_\_\_ - Equipment Wiring

### B. Materials furnished by the BAS contractor, but installed by others:

1. BAS Contractor to furnish the following to the Heating, Ventilation and Air Conditioning Contractor for installation by the HVAC contractor:
  - a. Control valves and temperature sensor wells for wet systems
  - b. Location of all wells and openings for temperature, pressure, and flow sensors for pipe systems

- c. Control dampers for air systems
- d. Variable Frequency Drives
- e. Location of all ducts and openings for temperature, pressure, flow, and humidity sensors for air systems.

### 1.03 QUALITY ASSURANCE

- A. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the specification requirements.
- B. Install system using competent workmen who are fully trained and factory certified in the installation of temperature control equipment. The factory certified diplomas shall be readily available at the request of the owner or associate engineer.
- C. Single source responsibility of supplier shall be the complete installation and proper operation of the BAS and control system and shall include debugging and proper calibration of each component in the entire system. The BAS must be supplied and installed by the same control contractor. Only Factory Authorized Distributors will be considered for installation. The letting of separate contracts by the prime HVAC Contractor for the Control System and a separate contract for its installation by a third party installer is strictly prohibited.
- D. Supplier shall have an in-place support facility within 50 miles of the site with technical staff, spare parts inventory and all necessary test and diagnostic equipment.
- E. All electronic equipment shall conform to the requirements of FCC Regulations, Part 15, Subpart B, Class A, governing radio frequency electromagnetic interference, and be so labeled.
- F. BAS shall comply with, and be listed at time of bid for the following Underwriters Laboratories Standards:
  - 1. UL 916 for Energy Management Equipment, per category PAZX for Energy Management Equipment.
  - 2. UL 864 for Control Units for Fire-Protective Signaling Systems, per category UUKL for Smoke Control System Equipment.
- G. Product shall be ISO 9001 Registered at the time of bid.
- H. Design and build all system components to be fault-tolerant.
  - 1. Satisfactory operation without damage at 110% and 85% of rated voltage and at plus 3-Hertz variation in line frequency.
  - 2. Static, transient and short-circuit protection on all inputs and outputs.
  - 3. Protect communication lines against incorrect wiring, static transients and induced magnetic interference.
  - 4. Network-connected devices to be AC-coupled or equivalent so that any single device failure will not disrupt or halt network communication.
  - 5. All Building / System Controllers shall have real time clocks and data file RAM with

battery and SRAM backup.

6. All controllers shall be EEPROM, flash driven.
7. The BAS Installer shall have a competent and factory certified Project Manager who is able to answer field questions, is aware of all schedules and schedule changes, and is responsible for the BAS Installer's work and the coordination of their work with all other trades. This Project Manager shall be available for on site and shall respond to design, programming, and equipment related questions. Failure to provide the above services shall be considered a substantial breach of Contract Documents.

#### 1.04 SUBMITTALS

- A. Submit 10 complete sets of drawings showing the kind of control equipment for each of the various systems and their functions, along with indications on the drawing of all original setpoints and calibration values, and setup parameters, and sequence of operation of the automation system. These drawings shall be submitted for approval to the Associate, together with a complete brochure describing the equipment and their functions and operation. Include all application software documentation (actual programs or their job-specific flow charts) with DDC system and schedule a review meeting with OSU and the Associate at least two weeks before installation and start up.
  1. Manufacturer's Product Data:
    - a. All equipment components
  2. Shop Drawings:
    - a. System wiring diagrams with sequence of operation for each system as specified.
    - b. Submit manufacturer's product information on all hardware items along with descriptive literature for all software programs to show compliance with specifications.
    - c. System configuration diagram showing all panel types and locations as well as communications network and workstations.
- B. Where installation procedures, or any part thereof, are required to be in accord with the recommendations of the manufacturer of the material being installed, printed copies of these recommendations shall be furnished to the Associate prior to installation. Installation of the item will not be allowed to proceed until the recommendations are received.

### **PART 2- PRODUCTS**

#### 2.00 BACnet CONFORMANCE

- A. The Building Automation System (BAS) contractor shall supply a BACnet (ANSI/ASHRAE 135-2004) compliant system. Each device category and its required compliance are listed below under sections F-H. BACnet compatible systems that employ the use of proprietary 'gateways' will not be accepted unless otherwise noted. All non-approved BAS Contractors shall supply, prior to bid, Protocol Implementation Conformance Statements (PICS), BACnet Interoperability Building Block (BIBB) summaries or Device Profile listings and a detailed listing of Read/Write capabilities to the Associate Engineer for final approval (see proposed equals).

- B. The BACnet system shall be capable of Internet Protocol (IP) communications. BACnet/IP or Annex J will be considered the basis of design. All other configurations must be submitted prior to bid, in writing, for final approval. These configurations shall include but not limited to, Annex H or third party BACnet tunneling routers.
- C. The primary Local Area Network (LAN) shall be based upon the ISO 8802-3 Ethernet standard and will be required for all Building Controllers, System Controllers and Operator Work Stations. The use of MS/TP communications for interconnecting the said devices is strictly prohibited. The installation of all Ethernet wiring, accessories, and connectors shall conform to the ISO standard and/or guidelines identified herein. The preferred connection media shall be Category 6, Unshielded Twisted Pair (UTP) wire. The maximum single network run shall not exceed more than 300 feet. If additional distance is needed, the use of switches (not hubs) or other Ethernet medias will be acceptable. However, the 'cascading' of more than 3 switches on a single segment will not be accepted. The BAS system may utilize the customer's Local Area Network (LAN) provided the bandwidth consumption is less than 10% of the total network bandwidth. Under no circumstances, shall the customer's LAN be subject to failure and/or abuse. In efforts to decrease liability, all BACnet devices that reside on the LAN must support the BACnet Broadcast Management Device (BBMD) scheme. Multi-casting or Global broadcasting will not be permitted without the use of a BBMD. The Ohio State Medical Center will require one BBMD device for every floor of every building. The Medical Center network will be segmented so that each floor will be a separate subnet from all others.
- D. The secondary or sub-network shall utilize the Master-Slave/Token-Passing protocol, as acknowledged by the ANSI/ASHRAE 135 standard. Proprietary RS-485 or equivalent links will not be considered unless otherwise noted. The MS/TP link shall operate at a 76.8 Kbps minimum, and utilize no more than 2 repeaters in any instance. Multi channel repeaters will not be permitted.
- E. The use of proprietary gateways to transmit input/output data, and/or related information, must reside on the Ethernet LAN and be approved, in writing, prior to the bid.
- F. **Workstation conformance (OWS):** The workstation must be scheduled or submitted to the BTL for future testing, under Device Profile B-OWS (Annex L of the BACnet standard) with support of the following BIBBs:

Alarm and Event Management BIBBs

AE-ACK-A, AE-ACK-B, AE-ASUM-A, AE-ASUM-B, AE-ESUB-A, AE-ESUM-B, AE-INFO-A, AE-INFO-B, AE-N-A, AE-N-E-B, AE-N-I-B

Device Management BIBBs

DM-BR-A, DN-DCC-A, DM-DCC-B, DM-DDB-A, DM-DDB-B, DM-DOB-A, DM-DOB-B, DM-LM-A, DM-LM-B, DM-OCD-A, DM-OCD-B, DM-RD-A, DM-RD-B, DM-TM-B, DM-TS-A, DM-UTC-A

Data Sharing BIBBs

DS-COV-A, DS-COV-B, DS-COVU-A, DS-COVU-B, DS-RP-A, DS-RP-B, DS-RPM-A, DS-RPM-B, DS-WP-A, DS-WP-B, DS-WPM-A, DS-WPM-B

Network Management BIBBs

NM-CE-A, NM-CE-B

Scheduling BIBBs

SCHED-A, SCHED-E-B, SCHED-I-B

Trending

T-ATR-A, T-ATR-B, T-VMT-A, T-VMT-E-B, T-VMT-I-B

- G. **Building Controller Conformance (BC):** The building controller must be certified and listed by BTL (BACnet Testing Laboratory) under Device Profile B-BC (Annex L of the BACnet standard) with support of the following BIBBs:

Alarm and Event Management BIBBs

AE-ACK-B, AE-ASUM-B, AE-ESUM-B, AE-INFO-B, AE-N-A, AE-N-E-B, AE-N-I-B

Device Management BIBBs

DM-BR-B, DM-DCC-B, DM-DDB-A, DM-DDB-B, DM-DOB-A, DM-DOB-B, DM-OCD-B, DM-RD-B, DM-TM-A, DM-TS-A, DM-TS-B, DM-UTC-A, DM-UTC-B

Data Sharing BIBBs

DS-COV-A, DS-COV-B, DS-COVU-A, DS-COVU-B, DS-RP-A, DS-RP-B, DS-RPM-A, DS-RPM-B, DS-WP-A, DS-WP-B, DS-WPM-B

Network Management BIBBs

NM-CE-A, NM-CE-B

Scheduling BIBBs

SCHED-A, SCHED-E-B, SCHED-I-B

Trending

T-ATR-B, T-VMT-E-B, T-VMT-I-B

- H. **Advanced Application Controller Conformance (AAC):** The AAC must be certified and listed by BTL (BACnet Testing Laboratory) under Device Profile B-AAC (Annex L of the BACnet standard) with support of the following BIBBs:

Alarm and Event Management BIBBs

AE-ACK-B, AE-ASUM-B, AE-ESUM-B, AE-INFO-B, AE-N-E-B, AE-N-I-B

Device Management BIBBs

DM-BR-B, DM-DCC-B, DM-DDB-A, DM-DDB-B, DM-DOB-A, DM-DOB-B, DM-LM-B, DM-OCD-B, DM-RD-B, DM-TM-A, DM-TS-B, DM-UTC-B

Data Sharing BIBBs

DS-COV-A, DS-COV-B, DS-COVU-A, DS-RP-A, DS-RP-B, DS-RPM-A, DS-RPM-B, DS-WP-A, DS-WP-B, DS-WPM-B

Network Management BIBBS

NM-CE-A

Scheduling BIBBs

SCHED-E-B, SCHED-I-B

Trending

T-ATR-B, T-VMT-E-B, T-VMT-I-B

- I. **Application Specific Controllers (ASC):** ASCs will not be permitted on this project. The minimum level BACnet Controller that will be accepted by The Ohio State University Medical Center shall be listed as a B-AAC device under the BTL certification process.
- J. **Read / Write Properties:** The entire BACnet BAS system (all OWS, BC, AAC and ASC devices) shall support the following Read/Write properties within the given BACnet objects and shall permit dynamic creation and deletion thereof.

Analog Input Object

Read and Write Properties: Description, Name, Value, COV Increment, Out of Service, Reliability

Read Only Properties: Type, Units, Status Flags, Event State

Analog Output Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability

Read Only Properties: Type, Units, COV Increment, Status Flags, Event State, Priority Array

Analog Variable Object

Read and Write Properties: Description, Name, Value, Units, COV Increment, Out of Service, Reliability

Read Only Properties: Type, Status Flags, Event State

Binary Input Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability

Read Only Properties: Type, Status Flags, Event State

Binary Output Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability, Minimum On/Off time

Read Only Properties: Type, Status Flags, Event State, Priority Array

Binary Variable Object

Read and Write Properties: Description, Name, Value, Out of Service, Reliability

Read Only Properties: Type, Status Flags, Event State

Event Enrollment Object

Read and Write Properties: Description, Name, Notification Class, Event Enable, Event Parameter, Event Type, Object Reference

Read Only Properties: Type, Event State, Event Time Stamps, Notification Type, Acknowledged Transactions

Notification Class Object

Read and Write Properties: Description, Name, Priority, Recipient List

Read Only Properties: Type, Notification Class

Calendar Object

Read and Write Properties: Description, Name

Read Only Properties: Type, Value

Schedule Object

Read and Write Properties: Description, Name, Object Reference, Weekly Schedule, Effective Period, Schedule Exceptions

Read Only Properties: Type, Value

Trendlog Object

Read and Write Properties: None

Read Only Properties: Description, Name, Type, Notification Class, Event Enable, Event State, Event Time Stamps, Notification Type, Acknowledge Transactions, Log Enabled, Start/Stop Time, Log Interval

Program Object

Read and Write Properties: Description, Name, Out of Service, Reliability, Program Change

Read Only Properties: Type, Status Flags

Loop Object

Read and Write Properties: Description, Name, Value, COV Increment, Out of Service, Reliability, Tuning Parameters, Action, Controlled Variable

Read Only Properties: Event State, Status Flag, Type

File Object

Read and Write Properties: Description, Name

Read Only Properties:                      Type

## 2.01 NETWORKING COMMUNICATIONS

- A. The design of the BAS network shall integrate operator workstations and stand-alone DDC Controllers on a peer-to-peer communications network, and other devices on other networks. The network architecture shall consist of the following four levels:
1. A district-wide Ethernet communications network based on the BACnet/IP protocol (Annex J.)
  2. An auto-dial/auto-answer BACnet PTP telecommunications network.
  3. A building-wide peer-to-peer communications network between Building Controllers utilizing the BACnet protocol over Ethernet media.
  4. BACnet MS/TP secondary networks extended from appropriate Building Controllers to associated Advanced Application Controllers.
- B. Access to system data shall not be restricted by the hardware configuration of the building automation system. The hardware configuration of the BAS network shall be totally transparent to the user when accessing data or developing control programs.
- C. District-wide Ethernet Communications Network (Primary Connection)
1. Local within this building, provide one Ethernet link between the campus-wide BACnet/IP virtual network and the building-wide peer-to-peer network (Building Controller network). Only one peer-to-peer Building Controller per floor shall provide the interface to the BACnet/IP virtual network for remote monitor, remote manual control, remote alarm, and remote programming of sequences of any and all building-wide points (BBMD device).
  2. Remote at the Central Utilities office (Room 009), provide one Ethernet link for monitor, control, alarm, displaying graphics, and simultaneous programming of sequences. If programming of sequences cannot be accomplished simultaneously while performing monitor, control, alarm, and displaying graphics, then provide a second Ethernet link to allow for simultaneous programming.
  3. All Ethernet communications shall include software management and control for both access and privilege. The remote Central Utilities office shall manage all rights for access and privilege per each remote location, for remote monitor, remote manual control, remote alarm, and remote programming of sequences of any and all building-wide points.
- D. Auto-dial/Auto-answer Telecommunication Network (Secondary connection):
1. BACnet PTP communications shall be provided to allow Building Controllers to communicate with remote operator stations and/or remote terminals on an intermittent basis via telephone lines, as indicated in the sequence of operations.
  2. Auto-dial Building Controllers shall automatically place calls to workstations to report alarms or other significant events.
    - a. Building Controllers shall be able to store a minimum of 20 phone numbers of at

least 20 digits. Retry a single primary number at a fixed interval until successful.

- b. The auto-dial program shall include provisions for handling busy signals, "no answers" and incomplete data transfers. Provide as a minimum 3 secondary numbers when communications cannot be established with the primary device.
3. Operators at dial-up workstations shall be able to perform all control functions; all report functions and all database generation and modification functions as described for workstations connected via the network. Routines shall be provided to automatically answer calls from remote Building Controllers. The fact that communications are taking place with remote Building Controllers over telephone lines shall be completely transparent to an operator.
  - a. An operator shall be able to access remote buildings by selection of any facility by its logical name. The workstation dial-up program shall store the phone numbers of each remote site, so the user shall not be required to remember or manually dial telephone numbers.
  - b. A PC workstation may serve as an operator device on a network, as well as a dial-up workstation for multiple auto-dial DDC Controllers or networks. Alarm and data file transfers handled via dial-up transactions shall not interfere with network activity, nor shall network activity keep the workstation from handling incoming calls.
4. Dial-up communications shall make use of Hayes compatible modems and voice-grade telephone lines. Provide modems rated at 56K baud with auto ranging. System access to be provided through phone lines to the existing campus Front End Computer. If applicable, the cost of the phone line installation is the responsibility of this contractor and should be included in this contract.

E. Building-wide Peer-to-Peer Communications Network:

1. Operator workstations and Building Controllers shall directly reside on an Ethernet network such that communications may be executed directly between Building Controllers and workstations on a peer-to-peer basis, without requirement for any device to operate or manage the network. A portion of the network management is built into each of the 'peer-to-peer members. 'Peer-to-peer' refers to controllers that (when interconnected) will act independently as equals, without a network manager, and will communicate in a token passing protocol with each other to pass data packet information for the purpose of building-wide monitoring and control. A special data packet called the 'token' is constantly and continually 'passed' to every member of the peer-to-peer communications network. Any peer-to-peer device on the network can send a packet of data only when it has the 'token'. Any peer-to-peer device on this network can request data from, or send data to, any other device on the network. With this procedure, token ensures that data collisions do not occur, and assures that all members of the network get equal opportunity for all data on the network.
2. Systems that operate via polled response or other types of protocols that rely on a network manager, file server, or similar device to manage panel-to-panel communications will not be considered.
3. All operator devices either resident on the peer-to-peer network, or connected via dial-up modems shall have the ability to access all point status and application report data or

execute control functions for any and all other devices via the peer-to-peer network. Access to data shall be based upon logical identification of building equipment. No hardware or software limits shall be imposed on the number of devices with global access to the peer-to-peer network data.

4. Network design shall include the following provisions:
  - a. Provide high-speed data transfer rates for alarm reporting, quick report generation from multiple controllers and upload/download efficiency between network devices. System performance shall ensure that an alarm occurring at any DDC Controller is displayed at workstations and/or alarm printers within 5 seconds.
  - b. Support of any combination of DDC Controllers and operator workstations directly connected to the peer-to-peer network. A minimum of 50 devices shall be supported on a single network (including MS/TP).
  - c. Message and alarm buffering to prevent information from being lost.
  - d. Error detection, correction and retransmission shall be included to guarantee data integrity.
  - e. Synchronization of real-time clocks, to include automatic daylight savings time updating between all controllers shall be provided. Universal Time Coordinate based upon Greenwich Mean Time must be supported. (All BC devices must have Real Time Clocks with battery and SRAM backup, see section 1.03 H)
5. Acceptable protocols for intercommunications between building-wide peer-to-peer Building Controllers:
  - a. BACnet over Ethernet (BACnet/IP between subnets only)

F. Local Area (communications) Network (LAN):

1. This communications network shall be limited to Building Controllers and Advanced Application Controllers and shall communicate bi-directionally with the BACnet peer-to-peer network.
2. Advanced Application Controllers shall be arranged on the LAN's in a functional relationship to the corresponding Building Controllers. For example, a VAV Advanced Application Controller serving a VAV terminal box shall be connected on a MS/TP network from the Building Controller that is controlling the corresponding air handling unit.
3. A maximum of 64 Advanced Application Controllers may be configured on any individual LAN from any Building Controller to insure adequate global data and alarm response times.
4. Acceptable protocols for intercommunications between Advanced Application Controllers and Building Controllers, are as follows:
  - a. BACnet (MS/TP), BACnet over Ethernet

2.02 BUILDING CONTROLLER

- A. DDC (stand-alone) Controllers shall have a 32 bit processor with EEPROM, flash driven operating system (OS). They shall also be multi-tasking, multi-user, real-time digital control processors and permit I/O expansion for control / monitoring of up to 48 I/O. Controller size shall be sufficient to fully meet the requirements of this specification.
- B. Each Building Controller shall have sufficient flash memory (EEPROM), a minimum of 2 megabyte, to support its own operating system. In addition, there shall be additional SRAM memory for database handling: Both the EEPROM and SRAM shall permit full implementation and support of all B-BC requirements of this specification, including:
  - 1. Control processes
  - 2. Energy management applications
  - 3. Alarm management applications including custom alarm messages for each level alarm for each point in the system.
  - 4. Historical/trend data for points specified
  - 5. Maintenance support applications
  - 6. Custom processes
  - 7. Operator I/O
  - 8. Dial-up communications
  - 9. Manual override monitoring
- C. Each Building Controller shall support:
  - 1. Monitoring of the following types of inputs, without the addition of equipment outside of the Building Controller cabinet:
    - a. Analog inputs
      - 1) 4-20 mA
      - 2) 0-10 Vdc
      - 3) Thermistors
    - b. Digital inputs
      - 1) Dry contact closure
      - 2) Pulse Accumulator
      - 3) Voltage Sensing
  - 2. Each Building Controller shall be capable of providing the following control outputs without the addition of equipment outside the Building Controller cabinet:
    - a. Digital outputs (contact closure)
      - 1) Contact closure (motor starters, up to size 4)
    - b. Analog outputs

- 1) 4-20 mA
- 2) 0-10 Vdc
- 3) 0-135 Ohm (with external Transducer)

- D. Each Building Controller shall have a minimum of 10 percent spare (panel real estate) capacity for future point connection and shall support up to 48 I/O with modular expansion modules. The type of spares shall be in the same proportion as the implemented I/O functions of the panel, but in no case shall there be less than two spares of each implemented I/O type. Provide all processors, power supplies, database memory, program sequence memory, and communication controllers complete so that the implementation of any added point (within the above 10% spare) only requires the addition of the appropriate point input/output termination module, point sensor, and wiring.
1. Provide sufficient internal memory for the specified control sequences and have at least 25% of the memory available for future use.
  2. Building Controllers shall provide at least one RS-232C serial data communication ports (BACnet PTP compatible) for operation of operator I/O devices such as industry standard printers, operator terminals, modems and laptop portable operator's terminals. Building Controllers shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers or terminals. System-wide access must be provided at each mechanical equipment room through the local Building Controller. Panel mounted terminals are not required. Furthermore, all Building Controllers shall include a hardwired, concealed and secured, RJ-11 or RJ-45 jack for use by the Portable Operators Workstation. The local operator, using the Portable Operators Workstation, shall plug into this jack, and shall perform all monitoring, control, and programming of sequences for any and all building-wide points and sequences while standing at any Advanced Application Controller.
- E. As indicated in the point I/O schedule, the operator shall have the ability to manually override automatic or centrally executed commands at the Building Controller via local, point discrete, on-board supervised hand/off/auto operator override switches for digital control type points and gradual switches for analog control type points. These override switches shall be operable whether the panel processor is operational or not.
1. Switches shall be supervised and mounted either within the Building Controllers key-accessed enclosure, or externally mounted with each switch keyed to prevent unauthorized overrides.
  2. Building Controllers shall monitor the status of all overrides and inform the operator that automatic control has been inhibited. Building Controllers shall also collect override activity information for reports.
- G. Building Controllers shall provide local LED status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device. Graduated intensity LED's or analog indication of value shall also be provided for each analog output.
- H. Each Building Controller shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all panel components. The Building Controller shall provide both local and

remote annunciation of any detected component failures and for repeated failure to establish network communications.

- I. Isolation shall be provided at all peer-to-peer network terminations, as well as all field point termination's to suppress induced voltage transients consistent with current IEEE Standard C62.41.
- J. In the event of the loss of normal power, there shall be an orderly shutdown of all Building Controllers to prevent the loss of database or operating system software. Programs residing in memory shall be protected either by using EEPROM under capacitor backup or by an uninterruptible power source (battery backup). The backup power source shall have sufficient capacity to maintain volatile memory in event of an AC power failure. Where interruptible power source is rechargeable ( a rechargeable battery), provide sufficient capacity for a minimum of seventy-two hours backup. Charging circuitry, while the controller is operating under normal line power, shall constantly charge the rechargeable power source. A non-rechargeable power source shall not be permitted. Batteries shall be implemented to allow replacement without soldering.
  - 1. Upon restoration of normal power, the Building Controller shall automatically resume full operation without manual intervention.
  - 2. Should Building Controller memory be lost for any reason, the user shall have the capability of reloading the Building Controller via the local RS-232C port, via telephone line dial-in or from a network workstation PC.
- K. Building Controllers must comply with Section 2.02, A-J and 2.03. Panels that lose communication or control due to a single sensor failure are not permitted.
- L. Building Controllers will be used in each equipment room where major or more than two pieces of equipment are being controlled. The use of AAC or ASC devices for critical or main system equipment will not be permitted.
- M. All points associated with a given mechanical system (i.e., an air handling unit) will be controlled from a single Building Controller or point expansion panels from the respective master. (i.e., remote motor control centers). No points from a given mechanical system may be distributed among multiple panels - points must be run back to a single Building Controller dedicated to that mechanical system. Closed-loop control must never depend upon network communications. All inputs, program sequences, and outputs for any single DDC control loop shall reside in the same Building Controller.

### 2.03 BUILDING CONTROLLER RESIDENT SOFTWARE FEATURES

- A. General:
  - 1. All necessary software to form a complete operating system as described in this specification shall be provided.
  - 2. The software programs specified in this Section shall be provided as an integral part of Building Controllers and shall not be dependent upon any higher level computer for execution.
  - 3. Point naming convention shall be as referenced in Appendix A (see end of section). The BC shall support a 128 character object name length. BCs that only permit a 32 character length will not be permitted.

B. Control Software Description:

1. The Building Controllers shall have the ability to perform any or all of the following pre-tested control algorithms:
  - a. Two-position control
  - b. Proportional control
  - c. Proportional plus integral control
  - d. Proportional, integral, plus derivative control
2. Control software shall include a provision for limiting the number of times that each piece of equipment may be cycled within any one-hour period.
3. The system shall provide protection against excessive demand situations during start-up periods by automatically introducing time delays between successive start commands to heavy electrical loads. This feature shall be resident in all Binary Output objects. The use of custom programming to prevent an excessive demand on start-up shall not be required.
4. Upon the resumption of normal power, each Building Controller shall analyze the status of all controlled equipment, compare it with normal occupancy scheduling and turn equipment on or off as necessary to resume normal operations.

C. All programs shall be executed automatically without the need for operator intervention and shall be flexible enough to allow user customization. Programs shall be applied to building equipment as described in the Sequence of Operations. Building Controllers shall have the ability to perform any or all of the following energy management routines:

1. Time-of-day scheduling
2. 365 day Calendar-based scheduling
3. Holiday scheduling
4. Temporary schedule overrides
5. Start-Stop Time Optimization
6. Automatic Daylight Savings Time Switch over
7. Night setback control
8. Enthalpy switch over (economizer)
9. Peak demand limiting
10. Temperature-compensated duty cycling
11. Fan speed/ control
12. Heating/cooling interlock

13. Cold deck reset
14. Hot deck reset
15. Hot water reset
16. Chilled water reset
17. Condenser water reset
18. Chiller sequencing
19. Chiller load monitoring

D. Building Controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.

1. It shall be possible to use any of the following in a custom process:
  - a. Any system measured point data or status
  - b. Any calculated data
  - c. Any results from other processes
  - d. User-defined constants
  - e. Arithmetic functions (+, -, \*, /, square root, exponential, etc.)
  - f. Boolean logic operators (and/or, exclusive or, etc.)
  - g. On-delay/off-delay/one-shot timers
2. Custom processes may be triggered based on any combination of the following:
  - a. Time interval
  - b. Time-of-day
  - c. Date
  - d. Other processes
  - e. Time programming
  - f. Events (e.g., point alarms)
3. A single process shall be able to incorporate measured or calculated data from any and all other controllers on the network. In addition, a single process shall be able to issue commands to points in any and all other controllers on the network.
4. Processes shall be able to generate operator messages and advisories to operator I/O devices. A process shall be able to directly send a message to a specified device or cause the execution of a dial-up connection to a remote device such as a printer or

pager.

5. The custom control programming feature shall be compiled and documented via English language descriptors. These descriptors (comment lines) shall be viewable from local operator I/O devices to facilitate troubleshooting.
- E. Alarm management shall be provided to monitor and direct alarm information to operator devices. Each Building Controller shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic and prevent alarms from being lost. At no time shall the Building Controllers ability to report alarms be affected by either operator activity at a PC workstation, local I/O device or communications with other panels on the network.
1. All alarm or point change reports shall include the point's English language description and the time and date of occurrence.
  2. The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of six priority levels shall be provided for each point. Point priority levels shall be combined with user definable destination categories (PC, printer, DDC Controller, etc.) to provide full flexibility in defining the handling of system alarms. Each Building Controller shall automatically inhibit the reporting of selected alarms during system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point.
  3. Alarm reports and messages will be directed to a user-defined list of operator devices or PCs.
  4. In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 200 character alarm message to more fully describe the alarm condition or direct operator response.
    - a. Each Building Controller shall be capable of storing all custom alarm text for each alarm. The alarm text shall be unique and user defined; custom text shall be available for all BACnet alarms and shall reside in the BC, not in an OWS or PC.
    - b. Alarms shall have ability to be acknowledged from the local operator I/O device, (once the problem is resolved).
  5. In dial-up applications, operator-selected alarms shall initiate a call to a remote operator device.
- F. A variety of historical data collection utilities shall be provided for manual or automatic sampling, storing and displaying system data for points as specified in the I/O summary.
1. Building Controllers shall store point history data for selected analog and digital inputs and outputs:
    - a. Any point, physical or calculated may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each Building Controller. Two methods of collection shall be allowed; either by a pre-defined time interval, or upon a pre-defined change of value. Sample intervals of 1 second to 7 days shall be provided. Each Building Controller shall have a dedicated RAM-based buffer for trend data and shall be capable of

storing a minimum of 10,000 data samples.

2. Trend data shall be stored at the Building Controllers and uploaded to the workstation when retrieval is desired. Uploads shall occur based upon either; user-defined interval, manual command, or automatically when the trend buffers are full. Furthermore, the workstation shall notify the end-user if the hard drive capacity is low or if the database size is excessive. The OWS shall use a standard MSDE or SQL database handler for all trend log management. All trend data shall be available to all BACnet OWSs and for use in 3rd party personal computer applications. File format type to be comma delineated.
  3. Building Controllers shall also provide high resolution sampling capability for verification of control loop performance. Operator-initiated automatic and manual loop tuning algorithms shall be provided for operator-selected PID control loops as identified in the point I/O summary. Provide capability to view or print trend and tuning reports.
    - a. The Loop object shall display the most recent historical data of its own performance. It shall illustrate the number of setpoint crossings and the maximum and average deviation from setpoint.
    - b. Loop tuning shall be capable of being initiated either locally at the Building Controller, from a network workstation or remotely using dial-in modems. For all loop tuning functions, access shall be limited to authorized personnel through password protection.
- G. Building Controllers shall automatically accumulate and store run-time hours for digital input and output points as specified in the point I/O summary.
1. The totalization routine shall have a sampling resolution of one minute or less.
  2. The user shall have the ability to define a warning limit for run-time totalization. Unique, user-specified messages shall be generated when the limit is reached.
- H. Building Controllers shall automatically sample, calculate and store consumption totals on a daily, weekly or monthly basis for user-selected analog and digital pulse input type points as specified in the point I/O summary.
1. Totalization shall provide calculation and storage of accumulations of up to 99,999.9 units (e.g., kWh, gallons, BTU, tons, etc.).
  2. The totalization routine shall have a sampling resolution of one minute or less.
  3. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.
- I. Building Controllers shall have the ability to count events such as the number of times a pump or fan system is cycled on and off. Event totalization shall be performed on a daily, weekly or monthly basis for points as specified in the point I/O summary.
1. The event totalization feature shall be able to store the records associated with a minimum of 9,999.9 events before reset.
  2. The user shall have the ability to define a warning limit. Unique, user-specified messages, up to 200 characters, shall be generated when the limit is reached.

J. Advanced Application Controllers:

1. Each Building Controller shall be able to extend its performance and capacity through the use of remote Advanced Application Controllers. Each Advanced Application Controller shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each Advanced Application Controller shall be a microprocessor-based, 32 bit, multi-tasking, real-time digital control processor. Provide for control of terminal equipment including, but not limited to, the following:
  - a. Rooftop units
  - b. VAV Boxes
  - c. Heatpumps
  - d. Fancoils, Univents
  - e. Other terminal equipment or monitoring
2. Advanced Application Controllers must comply with Section 2.03, items A through I, and must be peer-to-peer devices. Advanced Application Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. Provide a hand/off/automatic switch for each digital output for manual override capability. Switches shall be mounted either within the controller's key-accessed enclosure, or externally mounted with each switch keyed to prevent unauthorized overrides. In addition, each switch position shall be supervised in order to inform the system that automatic control has been overridden. Switches will only be required for non-terminal applications or where controllers are readily accessible (not required for VAVs, Heatpumps, etc. that are above ceilings or inaccessible). All inputs and outputs shall be of the Universal type, allowing for additional system flexibility. A minimum of 12 global points (i.e. chilled water temperature, hot water temperature, etc.) must be able to be accessed through the Advanced Application Controller. If global point access is unavailable with the Advanced Application then a Building Controller must be furnished.
3. Each Advanced Application Controller shall support its own real-time operating system. Provide a time clock with battery backup to allow for stand-alone operation in the event that communication with its Building Controller is lost and to insure protection during power outages. In the event that the AAC does not support a real time clock (RTC) function and it is being used on critical or system level equipment as mentioned in section 2.03 J.1 then a Building Controller supporting RTC functionality shall be used in its place. AAC devices without RTC functionality will be permitted for use on terminal or unitary equipment such as VAV boxes, fancoils, heatpumps, univents and auxiliary monitoring and control.
4. Provide each Advanced Application Controller with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM under capacitor backup (lithium or rechargeable battery backup will not be permitted). Advanced Application Controllers must be fully programmable with a minimum of 200 lines of code available for custom programming. All programs shall be field-customized to meet the user's exact control strategy requirements. Advanced Application Controllers utilizing pre-packaged or canned programs shall not be acceptable. As an alternative, provide Building Controllers

for all central equipment in order to meet custom control strategy requirements.

5. Programming of Advanced Application Controllers shall utilize the same language and code as used by Building Controllers to maximize system flexibility and ease of use. Should the system controller utilize a different control language, provide a Building Controller to meet the specified functionality.
6. Local alarming and trending capabilities shall be provided for convenient troubleshooting and system diagnostics. Alarm limits and trend data information shall be user-definable for any point.
7. Each controller shall have connection provisions for a portable operator's terminal. This tool shall allow the user to display, generate or modify all point databases and operating programs. All new values and programs may then be restored to EEPROM via the programming tool.
8. Advanced Application Controllers that lose communication with master panels, and/or lose control due to a single sensor failure, are not acceptable.
9. At all Advanced Application Controllers include a hardwired, concealed and secured, RJ-11 or RJ-45 jack for use by the Portable Operators Workstation. The local operator, using the Portable Operators Workstation, shall plug into this jack, and shall perform all monitoring, control, and programming of sequences for any and all building-wide points and sequences while standing at any Advanced Application Controller.
10. At all Advanced Application Controllers, include the point database of the following minimum building-wide system data:
  - a. Building Primary Hot Water Return and Supply Temperatures
  - b. Building Primary Chilled Water Return and Supply Temperatures
  - c. Building Common Outside Air Temperature
  - d. Database for 10 other building-wide points, as field selected by OSU.

#### 2.04 ADVANCED APPLICATION CONTROLLERS (AAC) FOR "ASC" USE

- A. Application Specific Controllers are not permitted for use unless otherwise approved by The Ohio State University Medical Center. AAC devices shall be used for all intended ASC functionality. ASCs, by default, do not support the required BIBBs, or Read/Write capabilities as desired by The Ohio State University Medical Center.
- B. Each AAC shall operate as a stand-alone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each AAC shall be a microprocessor-based, 32-bit, multi-tasking, real-time digital control processor.
- C. The use of these AACs is limited to the monitor and control of building HVAC equipment that are outside of any mechanical equipment room, or outside of any electrical equipment room. All equipment located within, or controlled from within, any mechanical equipment room or electrical equipment room shall use the peer-to-peer Building Controller.
- D. The electrical power source for these Advanced Application Controllers shall be from local circuit breaker with appropriate fused, class 2, 100VA power-limited output. The breaker shall be

dedicated to the Advanced Application Controllers, labeled accordingly, and locked-out from inadvertent casual shutoff.

E. Advanced Application Controllers:

1. Provide for control of each piece of building HVAC equipment, including, but not limited to, the following:
  - a. Variable Air Volume (VAV) terminal boxes
  - b. Constant Air Volume (CAV) terminal boxes
  - c. Dual Duct (DD) terminal boxes
  - d. Unit Conditioners
  - e. Heat Pumps
  - f. Unit Ventilators
  - g. Fan Coil Units
2. Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. All inputs and outputs shall be of the universal type; that is, the outputs may be utilized either as modulating or two-state, allowing for additional system flexibility. Analog outputs shall be industry standard signals such as 24V floating control and 0-10 VDC allowing for interface to a variety of modulating actuators. Terminal equipment controllers or AACs utilizing proprietary control signals and actuators shall not be acceptable. As an alternative, provide Building Controllers or other AACs with industry standard outputs for control of all terminal equipment.
3. Each controller performing space temperature control shall be provided with a matching room temperature sensor. The sensor shall be 10K Type-3 thermistor based providing the following minimum performance requirements are met:
  - a. Accuracy:  $\pm 0.36^{\circ}\text{F}$
  - b. Operating Range:  $32^{\circ}$  to  $158^{\circ}\text{F}$
  - c. Set Point Adjustment Range:  $55^{\circ}$  to  $85^{\circ}\text{F}$  (adjustable)
  - d. Set Point Modes:
    - 1). Independent Heating
    - 2). Independent Cooling
    - 3). Night Setback Heating
    - 4). Night Setback Cooling
  - e. Calibration Adjustments: None required
  - f. Installation: Up to 500 ft. from Controller
  - g. Each room sensor shall also include the following auxiliary devices or options:
    - 1). Setpoint Adjustment Dial or equivalent buttons

- 2). Digital LED Temperature Indicator
  - 3). Override Switch or button
  - 4.). 2 % on board Humidity Sensor option
- h. The setpoint adjustment shall allow for modification of the temperature in a minimum of .5° F increments by the occupant. Setpoint adjustment may be locked out, overridden or limited as to time or temperature through software by an authorized operator at the central workstation, Building Controller, or via the portable operator's terminal.
  - i. The temperature indication shall be a digital display visible without removing the sensor cover.
  - j. An override switch shall initiate override of the night setback mode to normal (day) operation when activated by the occupant. The override function may be locked out, overridden or limited as to the time through software by an authorized operator at the central workstation, Building Controller, or via the portable operator's terminal.
4. Each controller shall perform its primary control function independent of other DDC Controller LAN communications, or if LAN communication is interrupted. Reversion to a fail-safe mode of operation during LAN interruption is not acceptable. The controller shall receive its real-time data from the Building Controller time clock to insure LAN continuity. Each controller shall include algorithms incorporating proportional, integral and derivative (PID) values for all applications. All PID values and biases shall be field-adjustable by the user via terminals as specified herein. This functionality shall allow for tighter control of space conditions and shall facilitate optimal occupant comfort and energy savings. Controllers that incorporate proportional and integral (PI) control algorithms only, without derivative (D) control algorithms, shall not be acceptable.
  5. Provide each terminal equipment controller with sufficient memory to accommodate point databases, operating programs, local alarming and local trending. All databases and programs shall be stored in non-volatile EEPROM, EPROM and PROM, or capacitor backup. The controllers shall be able to return to full normal operation without user intervention after a power failure of unlimited duration. Provide uninterruptible power supplies (UPS's) of sufficient capacities for all terminal controllers that do not meet this protection requirement. Operating programs shall be fully customizable for specific applications (programming language shall be identical to the Building Controllers). In addition, specific applications may be modified to meet the user's exact control strategy requirements, allowing for additional system flexibility. Controllers that require factory changes of any applications or that are algorithm based will not be acceptable.
  6. Variable Air Volume (VAV) Box Controllers:
    - a. As a minimum, shall support the following types of applications for pressure independent terminal control:
      - 1). VAV, cooling only
      - 2). VAV, with hot water reheat
      - 3). VAV, with electric reheat
      - 4). VAV, fan-powered
      - 5). VAV, fan-powered, with hot water reheat

6). VAV, fan-powered, with electric reheat

- b. All VAV box control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory changes of any applications or that are algorithm based will not be acceptable
7. The VAV box controller shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F (0° to 50°C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).
- a. The VAV controller shall include a differential pressure transducer that shall connect to the terminal unit manufacturer's standard averaging air velocity sensor to measure the velocity pressure in the duct. The controller shall convert this value to actual airflow in cfm. Single point air velocity sensing is not acceptable. The differential pressure transducer shall have a measurement range of 0 to 1 inWC and measurement accuracy of  $\pm 5\%$  throughout its range, insuring primary air flow conditions shall be controlled and maintained to within  $\pm 5\%$  of setpoint at the specified parameters. The BAS contractor shall provide the velocity sensor if required to meet the specified functionality.
  - b. The VAV box controller shall include provisions for manual and automatic reset of the differential pressure transducer in order to maintain stable control and insuring against drift over time. Reset shall be accomplished by stroking the terminal unit damper actuator to 0%, full closed, position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the end user desires. Manual reset may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Reset of the transducer at the controller location shall not be necessary.
  - c. The VAV box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within  $\pm 1.5^\circ\text{F}$  (adj.) of setpoint at the room sensor location.
  - d. The VAV box controller performing space heating control shall incorporate a program allowing for modulation of a hot water reheat valve, or cycling up to three (3) stages of electric reheat, as required to satisfy space heating requirements. Each controller shall also incorporate a program that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space cooling requirements. This algorithm shall function to signal the respective DDC Controller to perform the required discharge temperature reset in order to maintain space temperature cooling setpoint.
8. Constant Air Volume (CAV) Box Controllers:

- a. As a minimum, shall support the following types of applications for pressure independent terminal control:
  - 1). CAV, cooling only
  - 2). CAV, with hot water reheat
  - 3). CAV, with electric reheat
- b. All CAV box control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.
- c. The CAV box controller shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC, allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).
- d. The CAV controller shall include a differential pressure transducer that shall connect to the terminal unit manufacturer's standard averaging air velocity sensor to measure the velocity pressure in the duct. The controller shall convert this value to actual airflow in cfm. Single point air velocity sensing is not acceptable. The differential pressure transducer shall have a measurement range of 0 to 1 inWC and measurement accuracy of  $\pm 5\%$  throughout its range, insuring primary air flow conditions shall be controlled and maintained to within  $\pm 5\%$  of setpoint at the specified parameters. The BAS contractor shall provide the velocity sensor if required to meet the specified functionality.
- e. The CAV box controller shall include provisions for manual and automatic reset of the differential pressure transducer in order to maintain stable control and insuring against drift over time. Reset shall be accomplished by stroking the terminal unit damper actuator to 0%, full closed, position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the end user desires. Manual reset may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Reset of the transducer at the controller location shall not be necessary.
- f. The CAV box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within  $\pm 1.5^\circ\text{F}$  (adj) of setpoint at the room sensor location.
- g. Each controller performing space heating control shall incorporate an algorithm allowing for modulation of a hot water reheat valve or cycling up to three (3) stages of electric reheat as required to satisfy space heating requirements. Each controller shall also incorporate a program that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space

cooling requirements. This program shall function to signal the respective DDC Controller to perform the required discharge temperature reset in order to maintain space temperature cooling setpoint. Control of the terminal unit damper to maintain cooling setpoint shall not be permitted. As an alternative, Building Controllers or other Advanced Application Controller for the associated air handling equipment shall also directly control all CAV terminal units in order to provide the specified reset capability

- h. Each controller performing space pressurization control shall incorporate programs allowing for pressurization via the following methods as a minimum:
  - 1). Fixed air volume setpoints of supply and exhaust terminal units
  - 2). Updating of air volume setpoints of supply and exhaust terminal units
- i. Each supply and associated exhaust terminal controller may be set at a fixed air volume setpoint which is within a percentage of each other or an actual CFM differential to meet space pressurization requirements. The controllers shall incorporate provisions for independent occupied and unoccupied mode setpoints and differentials, allowing for additional flexibility. Applications requiring updating of air volume setpoints depending on a variable volume of air leaving the space either through the exhaust terminal(s) or other exhaust ducts shall utilize supply terminal unit controllers incorporating programs to allow for "tracking" of space exhaust(s) to maintain the required air volume differential.
- j. Terminal unit tracking shall be accomplished via actual measurement of terminal unit air volumes as previously specified. Controllers which track within a range of CFM's versus actual CFM setpoints shall not be acceptable.
- k. Zeroing of the differential pressure transducer shall be accomplished as previously specified for VAV box controllers. However, the method of stroking the terminal unit damper to a 0% position shall not be permitted should the controlled space(s) require constant pressurization or 24-hour per day operation. Controllers performing under 24-hour per day operation requirements shall incorporate an 'Auto-zero' auxiliary device(s) which functions to automatically zero the transducer without changing the damper position. This shall be accomplished by temporarily disengaging the transducer from the air velocity sensor so that a 0 cfm air volume reading is forced. The control damper position remains unchanged, as originally controlled before the start of the 'Auto-zero' recalibration. This shall automatically occur on a once per 24-hour basis, thus ensuring system accuracy as previously specified. Provide auxiliary devices and programming as required to perform this function.
- l. Should a failure occur within the controller, the terminal unit damper shall automatically be positioned fully open or fully closed as previously defined by the operator. Controllers that revert to a pressure-dependent control mode during failure shall not be acceptable.

9. Dual-Duct (DD) Box Controllers:

- a. As a minimum, shall support the following types of applications for pressure independent terminal control:

- 1). DD - Constant Volume - Cold Duct & Hot Duct Air Velocity Sensors with

- optional auxiliary heat.
  - 2). DD - Constant Volume - Cold Duct & Outlet Air Velocity Sensors with optional auxiliary heat.
  - 3). DD - Variable Air Volume - Cold Duct & Hot Duct Air Velocity Sensors with optional auxiliary heat.
  - 4). DD - Variable Air Volume - Cold Duct & Outlet Air Velocity Sensors with optional auxiliary heat.
  - 5). DD -Variable Air Volume - Cold Duct & Hot Duct Air Velocity Sensors with changeover.
- b. All DD box control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.
  - c. The DD box controller shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).
  - d. The DD controller shall include a differential pressure transducer that shall connect to the terminal unit manufacturer's standard averaging air velocity sensor to measure the velocity pressure in the duct. The controller shall convert this value to actual airflow in cfm. Single point air velocity sensing is not acceptable. The differential pressure transducer shall have a measurement range of 0 to 1 inWC and measurement accuracy of  $\pm 5\%$  throughout its range, insuring primary air flow conditions shall be controlled and maintained to within  $\pm 5\%$  of setpoint at the specified parameters. The BAS contractor shall provide the velocity sensor if required to meet the specified functionality.
  - e. The DD box controller shall include provisions for manual and automatic reset of the differential pressure transducer in order to maintain stable control and insuring against drift over time. Reset shall be accomplished by stroking the terminal unit damper actuator to 0%, full closed, position so that a 0 cfm air volume reading is sensed. The controller shall automatically accomplish this whenever the end user desires. Manual reset may be accomplished by either commanding the actuator to 0% via the POT or by depressing the room sensor override switch. Reset of the transducer at the controller location shall not be necessary.
  - f. The DD box controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within  $\pm 1.5^\circ\text{F}$  (adj) of setpoint at the room sensor location.
  - g. Each controller performing space heating control shall incorporate a program allowing for modulation of a hot water reheat valve or cycling up to two (2) stages

of electric reheat as required to satisfy space heating requirements.

- h. Provide two air velocity sensors and transducers to match the application. For VAV applications, provide separate minimum and maximum air volume setting for heating and cooling ducts. For CAV applications, provide separate air volume set points for occupied and unoccupied modes.
- i. Zeroing of the differential pressure transducer shall be accomplished as previously specified for VAV box controllers. However, the method of stroking the terminal unit damper to a 0% position shall not be permitted should the controlled space(s) require constant pressurization or 24-hour per day operation. Controllers performing under 24-hour per day operation requirements shall incorporate an 'Auto-zero' auxiliary device(s) which function to automatically zero the transducer without changing the damper position. This shall be accomplished by temporarily disengaging the transducer from the air velocity sensor so that a 0 cfm air volume reading is forced. The control damper position remains unchanged, as originally controlled before the start of the 'Auto-zero' recalibration. This shall automatically occur on a once per 24-hour basis, thus ensuring system accuracy as previously specified. Provide auxiliary devices and programming as required to perform this function.

10. Unit Conditioner Controllers:

- a. As a minimum, shall support the following types of applications for terminal control:
  - 1). Fan coil units
  - 2). Induction units
  - 3). Pressure dependent terminal boxes
- b. As a minimum, shall support the following types of fan coil units:
  - 1). Fan Coil, 2-pipe, heating or cooling
  - 2). Fan Coil, 4-pipe, heating or cooling
  - 3). Fan Coil, cooling, and electric heating
  - 4). Fan Coil, 2-stage cooling, and electric heating
  - 5). Fan Coil, 2-stage cooling, and hot water heating
- c. As a minimum, shall support the following types of Induction units:
  - 1). Induction Unit, 2-pipe
  - 2). Induction Unit, 4-pipe
- d. As a minimum, shall support the following types of pressure dependent terminal control:
  - 1). Heating, or cooling
  - 2). Hot water reheat
- e. All Unit Conditioner control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes

or those that are algorithm based will not be acceptable.

- f. The Unit Conditioner controllers shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC, allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F (0° to 50°C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).
- g. The Unit Conditioner controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within  $\pm 1.5^{\circ}\text{F}$  (adj) of setpoint at the room sensor location.
- h. The Unit Conditioner controller performing space temperature control shall incorporate a program allowing for modulation of a hot water reheat and chilled water valve, or cycling up to three (3) stages of electric reheat and chilled water valve, as required to satisfy space heating requirements. Each controller shall also incorporate a program that allows for resetting of the associated air handling unit discharge temperature if required to satisfy space cooling requirements (if applicable). This program shall function to signal the respective DDC Controller to perform the required discharge temperature reset in order to maintain space temperature cooling setpoint.

#### 11. Heat Pump Controllers:

- a. As a minimum, shall support the following types of applications for heat pump terminal control:
  - 1). Heat Pump, water source
  - 2). Heat Pump, air-to-air source
  - 3). Heat Pumps, with ventilation air
  - 4). Heat Pump, with auxiliary heat
- b. All Heat Pump control applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.
- c. The Heat Pump controllers shall be powered from a 24 VAC source and shall function normally under an operating range of 20 to 28 VAC, allowing for power source fluctuations and voltage drops. The BAS contractor shall provide a dedicated power source and separate isolation transformer for each controller unable to function normally under the specified operating range. The controllers shall also function normally under ambient conditions of 32° to 130°F (0° to 50°C) and 10% to 95%RH (non-condensing). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).

- d. The Heat Pump controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within  $\pm 1.5^{\circ}\text{F}$  (adj) of setpoint at the room sensor location.
- e. The Heat Pump controller performing space temperature control shall permit full control of the Heatpump regardless of its configuration.

12. Unit Ventilator Controllers:

- a. As a minimum, shall support the following types of applications for heating only unit ventilator applications:
  - 1). Unit Ventilator, ASHRAE Cycle 1, 2 or 3
  - 2). Unit Ventilator, ASHRAE Cycle 1, 2 or 3 with auxiliary reheat
  - 3). Unit Ventilator, Nesbitt Cycle W
  - 4). Unit Ventilator, Nesbitt Cycle W with auxiliary reheat
- b. All Unit Ventilator controller applications shall be fully programmable such that a single controller may be used in conjunction with any of the above types of terminal units to perform the specified sequences of control. This requirement must be met in order to allow for future design and application changes and to facilitate system expansions. Controllers that require factory application changes or those that are algorithm based will not be acceptable.
- c. The Unit Ventilator controllers shall be powered from either a 115 or 230 VAC power source common to the unit ventilator. The controllers shall function normally under ambient conditions of 32° to 130°F and 10% to 95% (non-condensed). Provide each controller with a suitable cover or enclosure to protect the intelligence board assembly (unless mounted above ceilings or in a general area that is normally not accessible).
- d. The Unit Ventilator controller shall interface to a matching room temperature sensor as previously specified. The controller shall function to maintain space temperature to within  $\pm 1.5^{\circ}\text{F}$  (adj) of setpoint at the room sensor location.
- e. The Unit Ventilator controller shall also interface to averaging temperature sensor(s) located in the discharge or mixed air stream(s) as required by application. The sensor(s) must be 10-K type 3 thermistors, providing the following minimum performance requirements are met:
  - 1). Probe: Averaging type
  - 2). Accuracy:  $\pm .50^{\circ}\text{F}$
  - 3). Temperature Monitoring 0° to 180°F (-18° to 82°C)

2.05 PORTABLE OPERATOR'S TERMINAL (POT)

- A. Provide One (1) portable operator terminal (POT). The POT shall be a laptop configuration and plug directly into any control panel. Provide the BACnet BAS software as required to provide complete functionality for viewing and modifying of all data (including custom programs).
- B. Functionality of the portable operator's terminal connected at any controller:
  - 1. Access all controllers on the network.

2. Backup and/or restore DDC Controller databases for all system panels, not just the DDC Controller connected thereto.
  3. Display all point, selected point and alarm point summaries.
  4. Display trending and totalization information.
  5. Add, modify and/or delete any existing or new system point.
  6. Command, change setpoint, enable/disable any system point.
  7. Program and load custom control sequences as well as standard energy management programs.
- C. Connection of a POT to a distributed control processor shall not interrupt nor interfere with normal network operation in any way, prevent alarms from being transmitted or preclude centrally-initiated commands and system modification.
- D. Portable operator terminal access to controller shall be password-controlled.
- E. Portable operator terminal minimum hardware and performance criteria shall be as referenced in Appendix A.2.

#### 2.06 PERSONAL COMPUTER OPERATOR WORKSTATION

- A. Personal computer operator workstations shall be provided for command entry, information management, network alarm management and database management functions. All real-time control functions shall be resident in the controllers to facilitate greater fault tolerance and reliability. Personal computer operator workstation minimum hardware and performance criteria shall be as referenced in Appendix A.2.

#### 2.07 WORKSTATION OPERATOR INTERFACE SOFTWARE

- A. Basic Interface Description
1. Operator workstation interface software shall minimize operator training through the use of English language prompting, English language point identification and industry standard PC application software. The software shall provide, as a minimum, the following functionality:
    - a. Graphical viewing and control of environment
    - b. Scheduling and override of building operations
    - c. Collection and analysis of historical data
    - d. Definition and construction of dynamic and animated color graphic displays
    - e. Editing, programming, storage and downloading of controller databases
  2. Provide a graphical user interface, which shall minimize the use of a typewriter style keyboard through the use of a mouse or similar pointing device and "point and click" approach to menu selection. Users shall be able to start and stop equipment or change setpoints from graphical displays through the use of a mouse or similar pointing device.

- a. Provide functionality such that all operations can also be performed using the keyboard as a backup interface device.
  - b. Provide additional capability that allows at least 10 special function keys to perform often-used operations.
- 3. The software shall provide multi-tasking operating system such that alarm notification occurs while user is running other applications such as Word or Excel; trend data uploads occur in the background while other applications are running. The mouse shall be used to quickly select and switch between multiple applications. This shall be accomplished through the use of Microsoft Windows<sup>a</sup> or similar industry standard software that supports concurrent viewing and controlling of systems operations.
  - a. Provide functionality such that any of the following may be performed simultaneously, and in any combination, via user-sized windows: (Vector based graphics)
    - 1). Dynamic and animated color graphics and graphic control
    - 2). Alarm management coordinated with section 2.04.E.
    - 3). Time-of-day scheduling
    - 4). Trend data definition and presentation
    - 5). Graphic definition
    - 6). Graphic construction
  - b. If the software is unable to display several different types of displays at the same time, the BAS contractor shall provide at least two operator workstations.
- 4. Multiple-level password access protection shall be provided to allow the user/manager to limit workstation control, display and data base manipulation capabilities. Privileges shall be customizable for each operator; the main menu shall reflect the privileges upon log on showing only the applications appropriate for the operator.
  - a. Customizable such that operators can monitor, command, or edit an application or group of points. An operator can be defined with privileges for access to a building, group or buildings, or areas (labs--point names with the designation "lab"), by application: the operator has monitor, command, and edit capability for time of day schedules and calendars (only) for the entire campus: or by function: the operator (i.e. security guard) has ability to view/monitor all areas of the campus and receive alarms, etc.
  - b. A minimum of 50 unique passwords, including user initials, shall be supported.
  - c. Operators will be able to perform only those commands available for their respective passwords. Menu selections displayed shall be limited to only those items defined for the access level of the password used to log-on.
  - d. The system shall automatically generate a report of log-on/log-off time and system activity for each user.
  - e. User-definable, automatic log-off timers of from 5 to 60 minutes shall be provided to prevent operators from inadvertently leaving devices on-line as well as have the capability to generate a report of log-on, log-off time, parameters modified, and system activity for each user.

5. Software shall allow the operator to perform commands including, but not limited to, the following:
  - a. Start-up or shutdown selected equipment
  - b. Adjust setpoints
  - c. Add/modify/delete time programming
  - d. Enable/disable process execution
  - e. Lock/unlock alarm reporting for points
  - f. Enable/disable totalization for points
  - g. Enable/disable trending for points
  - h. Override PID loop setpoints
  - i. Enter temporary override schedules
  - j. Define holiday schedules
  - k. Change time/date
  - l. Automatic daylight savings time adjustments
  - m. Enter/modify analog alarm limits
  - n. Enter/modify analog warning limits
  - o. View limits
  - p. Enable/disable demand limiting for each meter
  - q. Enable/disable duty cycle for each load
  - r. Operator shall have ability to schedule reports to print at a pre-specified time and frequency and directed to displays, printers, disk or emails. The reports shall be capable of querying all BACnet devices for all BACnet data and shall be available in industry standard formats such as Acrobat, Microsoft Word, Microsoft Excel and Crystal Reports.

1) Summaries shall be provided for specific points, for a logical point group, for a user-selected group or groups or for the entire BACnet network without restriction due to the hardware configuration of the building automation system. At a minimum, the report function shall provide all required BACnet data for the previously identified BACnet objects in section 2.00 J.

#### B. Scheduling

1. Provide a graphical spreadsheet-type format for simplification of time-of-day scheduling and overrides of building operations. Provide the following spreadsheet graphic types as a minimum:

- a. BACnet schedules
  - b. BACnet calendars
2. Weekly schedules shall be provided for each building zone or piece of equipment with a specific occupancy schedule. Each schedule shall include columns for each day of the week as well as holiday and special day columns for alternate scheduling on user-defined days. Equipment scheduling shall be accomplished by simply inserting occupancy and vacancy times into appropriate information blocks on the graphic. In addition, temporary overrides and associated times may be inserted into blocks for modified operating schedules. After overrides have been executed, the original schedule will automatically be restored.
3. Zone schedules shall be provided for each building zone as previously described. Each schedule shall include all commandable points residing within the zone, unless custom programming is used to enable/disable the points. Each point may have a unique schedule of operation relative to the zone's occupancy schedule, allowing for sequential starting and control of equipment within the zone.
4. Monthly calendars, until the year 2020, shall be provided which allow for simplified scheduling of holidays and special days in advance. Holidays and special days shall be user-selected with the pointing device and shall automatically reschedule equipment operation as previously defined on the weekly schedules.

#### C. Collection and Analysis of Historical Data

1. Provide trending capabilities that allow the user to easily monitor and preserve records of system activity over an extended period of time. Any system point may be trended automatically at time-based intervals or changes of value, both of which shall be user-definable. Trend data may be stored on hard disk for future diagnostics and reporting. In addition, the BAS system shall automatically trend and archive all alarms and user activity (no exceptions).
2. Trend data report graphics shall be provided to allow the user to view all trended point data. The BAS system shall employ the use of Multiple Trend-Logs which may be customized to include up to 8 individual single trends in one viewable and printable format. Provide additional functionality to allow any trended data to be transferred easily to Microsoft Office, Excel ®. This shall allow the user to perform custom calculations such as energy usage, equipment efficiency and energy costs and shall allow for generation of these reports on high-quality plots, graphs and charts.
3. Provide additional functionality that allows the user to view trended data on trend graph displays. Displays shall be actual plots of both static and/or real-time dynamic point data. A maximum of 8 points may be viewed simultaneously on a single graph, with color selection and line type for each point being user-definable. Displays shall include an 'X' axis indicating elapsed time and a 'Y' axis indicating a range scale in engineering units for each point. The 'Y' axis shall have the ability to be manually or automatically scaled at the user's option. Different ranges for each point may be used with minimum and maximum values listed at the bottom and top of the 'Y' axis. All 'Y' axis data shall be color-coded to match the line color for the corresponding point.
  - a. Static graphs shall represent actual point data that has been trended and stored on disk. Exact point values may be viewed on a data window by pointing or

scrolling to the place of interest along the graph. Provide capability to print any graph on the system printer for use as a building management and diagnostics tool.

- b. Dynamic graphs shall represent real-time point data. Any point or group of points may be graphed, regardless of whether they have been predefined for trending. The graphs shall continuously update point values. At any time the user may redefine sampling times or range scales for any point. In addition, the user may pause the graph and take "snapshots" of screens to be stored on the workstation disk for future recall and analysis. As with static graphs, exact point values may be viewed and the graphs may be printed.

#### D. Dynamic Color Graphic Displays

1. Color graphic floor plan displays and system schematics for each piece of mechanical equipment, including air handling units, chilled water systems and hot water boiler systems, room level terminal unit equipment shall be provided by the BAS contractor as indicated in the point I/O summary of this specification to optimize system performance analysis and speed alarm recognition. The operator interface shall allow users to access the various system schematics and floor plans via a graphical penetration scheme, menu selection or text-based commands.
2. Dynamic temperature values, humidity values, flow values, percent load, and status indication shall be shown in their actual respective locations and shall automatically update to represent current conditions without operator intervention.
3. The windowing environment of the PC operator workstation shall allow the user to simultaneously view several graphics at a time to analyze total building operation or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.
4. Graphic generation software shall be provided to allow the user to add, modify or delete system graphic displays.
  - a. The BAS contractor shall provide libraries of pre-engineered screens and symbols depicting standard air handling unit components (e.g., fans, cooling coils, filters, dampers, etc.), complete mechanical systems (e.g., constant volume-terminal reheat, VAV, etc.) and electrical symbols.
  - b. The graphic package shall use a mouse or similar pointing device in conjunction with a drawing program to allow the user to perform the following:
    - 1) Define symbols
    - 2) Position and size symbols
    - 3) Define background screens
    - 4) Define connecting lines and curves
    - 5) Locate, orient and size descriptive text
    - 6) Define and display colors for all elements
    - 7) Establish correlation between symbols or text and associated system points or other displays
    - 8) Ability to import scanned images and CAD drawings in Autodesk®, DWG format.
  - c. Graphical displays can be created to represent any logical grouping of system

points or calculated data based upon building function, mechanical system, building layout or any other logical grouping of points that aids the operator in the analysis of the facility.

1) To accomplish this, the user shall be able to build graphic displays that include point data from multiple controllers.

5. Dynamic system status graphic of the site-specific architecture showing status of system hardware, including quantity and address of networks, field panels, terminal equipment controllers, and printers.
6. The BAS contractor shall employ the use of accurate floor plans as part of the overall graphics package. The floor plans shall illustrate the location of room sensors and equipment. In addition, the floor plans shall utilize a thermographic scheme to instantly alert the end user of hot and cold areas. The thermograph shall illustrate and automatically intensify the red and blue gradient fills for each area, as to indicate the severity of the overheating or overcooling problem.

E. System Configuration and Definition:

1. All temperature and equipment control strategies and energy management routines shall be definable and fully programmable by the operator. System definition and modification procedures shall not interfere with normal system operation and control.
2. The system shall be provided complete with all equipment and documentation necessary to allow an operator to independently perform the following functions:
  - a. Add/delete/modify stand-alone Building Controllers
  - b. Add/delete/modify stand-alone Advanced Application Controllers
  - c. Add/delete/modify operator workstations
  - d. Add/delete/modify Application Specific Controllers, if used
  - e. Add/delete/modify points of any type and all associated point parameters and tuning constants
  - f. Add/delete/modify alarm reporting definition for points
  - g. Add/delete/modify control loops
  - h. Add/delete/modify energy management applications
  - i. Add/delete/modify time and calendar-based programming
  - j. Add/delete/modify totalization for points
  - k. Add/delete/modify historical data trending for points
  - l. Add/delete/modify custom control processes
  - m. Add/delete/modify any and all graphic displays, symbols and cross-reference to point data

- n. Add/delete/modify dial-up telecommunication definition
  - o. Add/delete/modify all operator passwords
  - p. Add/delete/modify alarm messages
3. Definition of operator device characteristics, any controller's individual points, applications and control sequences shall be performed using instructive prompting software.
- a. All custom programming language must be line sequential, English text with a real time compiler. The operator shall be able to view all live data within the program with no exceptions. The use of secondary software or manual intervention shall not be required.
  - b. If programming must be done with the PC workstation off-line, the BAS contractor shall provide at least 2 operator workstations.
  - c. Inputs and outputs for any process shall not be restricted to a single DDC Controller, but shall be able to include data from any and all other network panels to allow the development of network-wide control strategies. Processes shall also allow the operator to use the results of one process as the input to any number of other processes (cascading).
  - d. Provide the capability to backup and store all system databases on the workstation hard disk. In addition, all database changes shall be performed while the workstation is on-line without disrupting other system operations. Changes shall be automatically recorded and downloaded to the appropriate controller. Similarly, changes made at any Controllers shall be automatically uploaded to the workstation, ensuring system continuity. The user shall also have the option to selectively download changes as desired.
  - e. Provide context-sensitive help menus to provide instructions appropriate with operations and applications currently being performed. The help menus shall be readily accessible by selecting an icon or by pressing a function button on the keyboard.

## 2.08 WEB INTERFACE

### A. General

1. Furnish a Web-based access interface to the EMS system based on a client-server architecture, and allow for an unlimited number of simultaneous users (with Windows 2003 Professional server). An operator shall be able to access all the information in the system via a standard Web browser. The Web-page software shall not require a per user licensing fee or annual fees.
2. The Web interface shall be a separate software package and be installed as an "overlay" of the standard EMS software. The use of an embedded Web interface with a standard EMS software package will be prohibited (software packages must be separate).

### B. Browser Technology

1. Browser shall be a standard version of Internet Explorer 5 (or higher) or Netscape 6 (or higher). No special vendor-supplied software shall be needed on the thin-client

computers running the above browsers. All information shall be viewable, real-time and updated automatically without user interaction.

### C. Web Display

1. Web page graphics shown on the browser shall be replicas of the EMS displays. Operators shall need no additional training to understand the information presented on the Web pages when compared to what is shown on the EMS displays.
2. The Web interface shall automatically discover and display new devices that are connected to the BACnet network. In addition, all objects and associated properties will be automatically displayed without "mapping" or user intervention.
3. An operator, via the Web, shall have the ability to:
  - a. Navigate real-time through the system
  - b. Change all setpoints
  - c. View and acknowledge active alarms
  - d. Configure the system to email alarms to any other computer on the wide-area network (WAN).
  - e. Create and edit building schedules
  - f. Trend any point or value and display graphically or in table format
  - g. Manually override any input, output or value.
  - h. Display a summary of overridden points
  - i. Create new users or user groups, assign access privileges and edit existing user access privileges
  - j. Link graphics to .PDF files, AutoCAD files and Visio files to display sequence of operations and as-built documentation.
  - k. View and edit programs, and all input and output points

### D. Web Page Generation

1. All "EMS" displays shall be converted to HTML files automatically. The operator shall not be required to program in HTML.
2. All Web page graphics shall have dynamic graphic links with full animation of system components.
3. The Web site shall automatically generate a "network" tree, indicating all devices connected to the network.

### E. Password Security and Activity Log

1. Access via the Web browser shall utilize the same hierarchal security scheme as the EMS system. User shall be asked to log in once the browser makes connection to the

Web-page. Once the user logs in, any and all changes that are made shall be tracked by the EMS system. The user shall be able to change only those items that the user has authority to change.

#### F. Hardware

1. The PC requirements for the Web interface shall be industry standard "off the shelf" technology. Furthermore, the Web interface software and standard EMS software shall be installed on the same PC.

### 2.08 FIELD DEVICES

- A. Temperature Sensors: Each temperature sensor shall match the requirements of the associated temperature controller and shall be based upon 10-K Type-3 thermistors. Each sensor shall be designed for the appropriate application (i.e., duct, immersion, etc.) and be provided with all necessary installation accessories. Ranges shall be selected to the middle of the control range. Temperature sensors must have a minimum accuracy of +/- 0.5 deg F or .5 % of scale; whichever will provide the least error in measurement.
1. Electronic: A modulating solid state controller with built-in detector, P, PI, or PID controller, as required, with continuous voltage or current output. Each controller shall have individual setpoint, proportional band, start point, and span adjustments. Input voltage shall be 24 VAC or less. Each controller to be provided with night setback, summer/winter switchover or remote reset capabilities as required. Controllers shall be of matching type to the input detectors and output drives or sequencers.
  2. Thermostat guards shall be provided where specified, indicated on control diagrams, or indicated on floor plans. Guards shall be firmly attached to wall and thermostat cover shall be visible through the guard. All room sensors in public areas will have concealed setpoint adjustments.
  3. All room sensors in classroom, office, or common spaces will have exposed set point adjustments locked to provide adjustment between 68 degrees and 72 degrees only.
  4. Install thermostats and sensors at 4'-6" AFF to bottom unless otherwise noted on Architectural Drawings. Coordinate installation with the work of other trades before any rough-ins are made.
  5. Duct Sensors: DDC duct sensors shall match the requirements of the associated controller incorporating an electrical signal to insure exact and proportional relationship between the measured variable and the transmitted signal. Static pressure sensors shall be mounted in temperature control panels with connecting sensor lines in hard copper. Where a device is used for sensing of Mixed Air Temperature or Preheat applications and the duct area is in excess of 24 square feet the instrument shall incorporate a capillary averaging element with a minimum length of 96 inches or a suitable array of duct sensors wired as a single input. Averaging sensors shall be used on any duct application where duct area exceeds 24 square feet.
  6. Provide temperature sensors as required to meet the sequence of operation; in addition, provide temperature sensors in the following locations: return air, mixed air and discharge air sections if not required by the sequence of operation.
- B. Humidity Sensors: The relative humidity transmitter monitors and transmits changes in humidity, accurate to +/- 2 % RH. Operating range shall be 0 to 99% RH.

- C. Pressure Sensors: Duct static pressure analog sensors shall be high accuracy +/-1% of range suitable for the low pressures and selected for at least 50% over range Sensors shall have industry standard 4-20 mA output and zero end span adjustments.
- D. Control Dampers (Multiple Blade Dampers): Automatic dampers furnished by the BAS Contractor shall be single blade or multiple blades as applicable. All dampers are to be sized to the application by the manufacturer using methods similar to control valve sizing. Dampers are to be installed by the HVAC Contractor under the supervision of the Temperature Control Contractor. All dampers furnished by air handling unit manufacturers must meet the requirements listed in this section. All blank-off plates and conversions necessary to install smaller than duct size dampers are the responsibility of the HVAC Contractor. All damper frames are to be constructed of No. 13 gauge galvanized sheet metal and shall have flanges for duct mounting. Damper blades shall not exceed 6 inches width. All blades are to be airfoil type construction in ducts with air velocities above 1500 FPM and will be equal to Ruskin RCD 50 control dampers with blade and jamb seals. In applications with velocities less than 1500 FPM control dampers will be equal to Ruskin RCD46 control dampers. Blades are to be suitable for high velocity performance. All damper bearings are to be made of nylon. Bushings that turn in the bearings are to be oil impregnated sintered metal. Dampers hung with blades mounted vertically shall be provided with thrust bearings. Butyl rubber seals are to be installed along the top and bottom of the frame and along each blade edge. Independent, self-compensating, stainless steel end seals shall be installed to insure minimum leakage between blade ends and damper frame. Seals shall provide a tight closing low leakage damper. Damper sections shall not exceed 48" in length or 16 sq. ft. and shall have minimum of one operator per damper section. All dampers in modulating applications shall have opposed blades. Dampers in two position services shall have parallel blades. Where sequence requires, submittals shall include damper sizes and leakage characteristics. Leakage shall not exceed 1 % at 4" W.C. when tested per AMCA Standard 500.
1. Control dampers will be sized by the temperature control contractor to the inside of the duct or duct liner whichever is smaller. Sizing of dampers to duct size and the subsequent cutting back of insulation to make dampers fit is unacceptable.
  2. Control dampers used for outside air or exhaust air applications will be installed a minimum of 6" away from wall penetrations to allow for external mounting of their respective damper motors. Jack shafting in these applications will only be allowed to prevent having to mount motors in the outside airstream. When internal damper motor mounting is required the sheet metal contractor shall provide access panels at each motor location to allow for ease of service.
- E. Damper Operators: Operators shall be electronic, spring return, low voltage (24VAC), and shall be properly sized so as to stroke the damper smoothly and efficiently throughout its range. Actuator responses shall be linear in response to sensed load.
1. Electronic damper motors for terminal boxes will be provided by the temperature control contractor and shipped to the terminal box manufacturer for mounting. Mounting charges shall be the responsibility of the terminal box manufacturer.
  2. Damper operators on outside air intake/exhaust shall be spring return closed.
  3. VAV Terminal Boxes using internal or proprietary actuators are unacceptable.
- F. Automatic Control Valves: All valves shall be equipped with throttling plugs and removable composition discs and shall be manufactured by Siemens or Belimo. All valves are to be sized by the Control Contractor and shall submit pressure drop calculations and guarantee sufficient size

to meet the requirements of the equipment being served. Valve operators shall be of such design so as to provide adequate operating power for valve positioning.

1. Reheat valves controlled by AACs in VAV terminal applications shall utilize electronic actuation and shall fail normally closed (capacitor or spring driven failsafe). All reheat valves serving Laboratories and/or Vivariums (animal) rooms shall be electronic actuation and include spring return, to fail normally closed.
  2. Three-way Valves: Three-way valves are to be of the three port mixing arrangement, designed expressly for mixing of two inlets and providing a common outlet. The use of reverse piped diverting valves shall not be acceptable. The Temperature Control Contractor will assist the HVAC Contractor in providing guidance as to the correct method of piping of all three-way valves. It is the responsibility of the HVAC contractor to evaluate the contract drawings for proper verification.
  3. Butterfly valves for air handling unit coil control are unacceptable. If high GPM requirements dictate the valve size to be greater than 6", then Temperature Control contractor shall provide two control valves for the application, and the HVAC Contractor shall install the two control valves, for parallel and/or sequenced operation.
  4. For all fan systems with separate pre-heat and separate 2<sup>nd</sup> heating coil. The pre-heat coil shall fail normally open, shall include separate analog output AO point for control, and separate analog input AI point for low-limit pre-heat discharge control. The separate 2<sup>nd</sup> heating coil shall fail normally closed, shall include separate analog output AO point, and separate analog input AI point for low-limit heating control.
  5. For all fan systems with a single hot water coil, the coil shall fail normally open (i.e. AHUs, Fancoils Univents, UHs, CUHs, etc.)
  6. Pressure drop through modulating control valves shall not exceed 7 feet. Control valves for 2-position applications shall be line sized.
- G Air Volume Measurement: Provide Tek-Air or Ebtron air flow measuring system including microprocessor panel and air flow measuring sensor struts as required to measure outside air intake flow as denoted on the Drawings.
1. DDC air flow measuring system shall have a velocity range from 350 to 6000 ft./min. with duct measurement accuracy (including repeatability, zero offset, and temperature compensation) of plus or minus 0.5 percent.
  2. Pilot tube arrays and differential pressure arrays are not acceptable.
  3. The air flow measurement stations shall include a digital LCD display that illustrates the actual CFM, not FPM or other variables.
- H Smoke Detectors shall be provided and installed by the HVAC contractor. The electrical contractor will provide the necessary interlock wiring for life safety functions.
- I Air Static and Velocity Pressure Transmitter: The pressure transmitter shall be used for measuring duct static or velocity pressure in variable air volume fan systems.
- J Low Limit Detection Thermostat: Low limit detection thermostats equal to Siemens 134-1511 shall be of the vapor tension capillary type having a sensing element a minimum of 20 feet in length. These thermostats shall be of the manual reset type. The elements shall be complete with

necessary fittings to permit installation in the duct so as to sense the correct discharge temperatures. One low limit detection thermostat will be installed for every 24 square feet of protected area and arranged so as to stop their respective units and close the outside air dampers in the event discharge temperatures fall below 38 degrees F. The normally closed contact shall be wired to the fan circuit and the normally open contact (close on alarm) shall be wired to a DDC input. One common circuit is suitable for multiple thermostats on a single AHU coil area.

- K Electric Thermostats: Heavy-duty snap action type with key operators rated at 10 FLA at 120 RIAC contacts suitable for the intended service. Provide manual selector switches as required in the sequence of operation.
- L Fan and Pump Proof: Proof points for air handling unit fans, exhaust fans and pumps will be accomplished through the use of current sensing relays at the motor control center or motor starters. Current sensing relays shall be split-core design, for installation over any single power lead. Current sensing relays shall include field adjustable set screw for amperage setpoint adjustment, and shall include integral LED status light to locally indicate the 'on' and 'off' condition.
- M Variable Frequency Drives: The Variable Frequency Drives (VFDs) shall be supplied under this contract. The VFD shall be manufactured by Siemens or ABB and shall be sized and designed to appropriately control the motor loads. All VFDs shall incorporate a user friendly LCD display that clearly illustrates the drives parameters and current status (sometimes called advanced display). The BAS contractor shall coordinate with the electrical and HVAC contractor to ensure the proper implementation, location and wiring of all VFDs. The BAS contractor will be responsible for all low voltage wiring, while the electrical contractor will be responsible for all high voltage or line / load side wiring.

## 2.09 LABELING

- A. Provide labels for all field devices including sensors, transducers, thermostats, and relays. Exception: Room temperature and/or humidity sensors shall not be labeled.
- B. Labels shall be black laminated plastic with white letters and adhesive backing or screw fasteners. Labels shall be located adjacent to device and permanently affixed to device mounting surface. Labels for sensors in pipes may be secured using chain around the sensor well.
- C. Labels shall include system virtual/pseudo point name as well as English language name of device being controlled or specific condition being sensed.
- D. Identify all control wiring at each end with a wire tags or labels.

## **PART 3- EXECUTION**

### 3.01 SEQUENCE OF OPERATION

### 3.02 ON-SITE TESTING

- A. Field Test: When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line. The installer shall complete all testing, calibrating, adjusting and final field tests. Verify that all systems are operable from local controls in the specified failure mode upon panel failure or loss of power. Upon completion of the work, notify the Owner, and/or Architect/Engineer that the system is ready for final tests and inspection.

- B. At the time of final inspection, this Contractor shall be represented by a person with the proper authority, who shall demonstrate, as directed by the Architect/Engineer, that his work fully complies with the purpose and intent of the Specifications and Drawings. Labor, services, instruments, and tools necessary for demonstrations and tests shall be provided by the Contractor.
- C. The Contractor shall test and adjust each instrument specialty and equipment furnished by him, prior to final acceptance. The Contractor shall demonstrate, for approval by the Architect/Engineer, subsystems operate as coordinated and properly functioning, integrated system.
- D. The Contractor shall furnish labor to provide adjustments and incidentals necessary to obtain the desired and intended results.
- E. The Contractor shall turn over a printed copy and electronic copy of the completed and debugged operating software to OSU at the conclusion of the two year warranty.

### 3.03 SERVICE AND GUARANTEE

- A. General Requirements: Provide all services, materials and equipment necessary for the successful operation of the entire BAS system for a period of two years after completion of successful performance test. Provide necessary material required for the work. Minimize impacts on facility operations when performing scheduled adjustments and non-scheduled work.
- B. Description of Work: The adjustment and repair of the system includes all computer equipment, software updates, transmission equipment and all sensors and control devices. Provide the manufacturer's required adjustments and all other work necessary.
- C. Personnel: Provide qualified personnel to accomplish all work promptly and satisfactorily. The OSU Medical Center shall be advised in writing of the name of the designated service representative, and of any changes in personnel.
- D. Systems Modifications: Provide any recommendations for system modification in writing to OSU. Do not make any system modifications, including operating parameters and control settings, without prior approval from OSU. Any modifications made to the system shall be incorporated into the operations and maintenance manuals, and other documentation affected.
- E. Software: Provide all software updates and verify operation in the system. These updates shall be accomplished in a timely manner, fully coordinated with the system operators, and shall be incorporated into the operations and maintenance manuals, and software documentation.

### 3.04 TRAINING

- A. The Contractor shall provide competent and certified instructors to give full instruction to designated personnel in the adjustment, operation and maintenance of the system installed rather than a general training course. Instructors shall be thoroughly familiar with all aspects of the subject matter they are to teach. All training shall be held during normal work hours of 8:00 a.m. to 4:30 p.m. weekdays as follows:
- B. Provide 40 hours of training for the OSU Medical Center operating personnel. Training shall include:

1. Explanation of drawings, operations and maintenance manuals
  2. Walk-thru of the job to locate control components
  3. Operator workstation and peripherals
  4. Building Controller, Advanced Application Controller operation/function
  5. Operator control functions including graphic generation and field panel programming
  6. Operation of portable operator's terminal
  7. Explanation of adjustment, calibration and replacement procedures
- C. Provide 8 hours of additional training quarterly for a period of one year from final completion of the project.
- D. Since OSU may require personnel to have more comprehensive understanding of the hardware and software, additional training must be available from the Contractor. If OSU requires such training, it will be contracted at a later date. Provide description of available local and factory customer training.

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END OF APPENDIX A