SECTION 23 09 23

DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC

PART 1 – GENERAL

1.1 DESCRIPTION

A. The control system(s) shall be as indicated on the project documents, point list, drawings and described in these specifications. This scope of work shall include a complete and working system including all engineering, programming, controls and installation materials, installation labor, commissioning and start-up, training, final project documentation and warranty.

C. The Controls Contractor’s work shall include all labor, materials, special tools, equipment, enclosures, power supplies, software, software licenses, Project specific software configurations and database entries, interfaces, wiring, tubing, installation, labeling, engineering, calibration, documentation, submittals, testing, verification, training services, permits and licenses, transportation, shipping, handling, administration, supervision, management, insurance, Warranty, specified services and items required by the Contract for the complete and fully functional Controls Systems.

D. Following control devices and systems shall be used to provide the functional requirements of HVAC equipment and systems.

1. Direct Digital Control (DDC) of HVAC equipment and systems with capability to control electronic valves and dampers.

F. The new system shall include interface to existing systems and equipment shall operate and function as one complete system including one database of control point objects and global control logic capabilities. Facility operators shall have complete operations and control capability over all systems, new and existing including; monitoring, trending, graphing, scheduling, alarm management, global point sharing, global strategy deployment, graphical operations interface and custom reporting as specified. Modify the existing ECC, if necessary, to accommodate the additional control points.

G. The control subcontractor shall supply as required, all necessary hardware equipment and software packages to interface between any existing and new system Network Area Controllers (NAC) as part of this contract. Number of area controllers required is dependent on the type and quantity of devices, hardware and software points provided. Network area controllers are same as remote controller units (RCU).

H. The control systems shall be designed such that each mechanical system shall operate under stand-alone mode. Temperature Controls contractor shall provide controllers for each mechanical system. In the event of a network communication failure, or the loss of any other controller, the control system shall continue to operate independently. Failure of the ECC shall have no effect on the field controllers, including those involved with global strategies.

I. The Top End of the NAC shall communicate using American Society of Heating and Refrigerating Engineers/American National Standards Institute (ASHRAE/ANSI) Standard 135(BACnet) protocol. The NAC shall reside on the BACnet/IP Ethernet (ISO 8802-3) local area network, and provide information via standard BACnet object types and application services. The Bottom End of the NAC, the unit level controllers and all other field devices shall reside on the LonTalk FTT-10a network, and provide data using LonMark standard network variable types and configuration properties.

J. The intent of this specification is to provide a peer-to peer networked, stand-alone, distributed control system. The ECC requires the incorporation of LonWorks Technologies using Free Topology Transceivers (FTT-10), and specific conformance to the LONMARK Interoperability Association’s v3.0 Physical and logical Layer guidelines in all (NAC) Network Area Controllers, Remote Control Unit controllers, unitary terminal unit controllers and other LonMark compliant field devices. The minimum Baud rate shall be 78,000 Baud for FTT-10 and 1,250,000 Baud for FTT-1250.

   1. LonTalk communications protocol will be used on the communication network between RCU controllers and LonWorks controllers and devices to assure interoperability between all devices within the network.
   2. The ECC shall provide communication to all LonTalk data variables as defined in input/output point schedule and as required to accomplish sequence of operation as specified.
   3. Power wiring shall not be run in conduit with communications trunk wiring or signal or control wiring operating at 100 volts or less.

K. The control system shall accommodate a minimum of 20 users simultaneously, and the access to the system should be limited only by operator password.

L. Acceptable Systems: Facility Explorer by Johnson Controls: Each MER shall have its own FX-60 controllers connected to the Ethernet.

1.2 RELATED WORK

B. Section 23 05 11, COMMON WORK RESULTS FOR HVAC AND STEAM GENERATION.

F. Section 23 21 13, HYDRONIC PIPING and Section 23 22 13, STEAM AND CONDENSATE HEATING PIPING.

H. Section 23 73 00, INDOOR CENTRAL-STATION AIR-HANDLING UNITS.

J. Section 23 31 00, HVAC DUCTS AND CASINGS.

L. Section 23 05 93, TESTING, ADJUSTING, AND BALANCING FOR HVAC.

M. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

N. Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS.

O. Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW).

1.3 DEFINITION

A. Algorithm: A logical procedure for solving a recurrent mathematical problem; A prescribed set of well-defined rules or processes for the solution of a problem in a finite number of steps.

B. ACU: Auxiliary Control Unit (ACU) used for controls of air handling units, reports to RCU.

C. Analog: A continuously varying signal value (e.g., temperature, current, velocity etc.

D. BACnet: Building Automation Control Network Protocol, ASHRAE Standard 135.

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

F. Binary: A two-state system where a high signal level represents an "ON" condition and an "OFF" condition is represented by a low signal level.

G. BMP or bmp: Suffix, computerized image file, used after the period in a DOS-based computer file to show that the file is an image stored as a series of pixels.

H. Bus Topology: A network topology that physically interconnects workstations and network devices in parallel on a network segment.

I. Control Unit (CU): Generic term for any controlling unit, stand-alone, microprocessor based, digital controller residing on secondary LAN or Primary LAN, used for local controls or global controls. In this

specification, there are three types of control units are used; Unitary Control Unit (UCU), Auxiliary Control Unit (ACU), and Remote Control Unit (RCU).

J. Deadband: A temperature range over which no heating or cooling is supplied, i.e., 22-25 degrees C (72-78 degrees F), as opposed to a single point change over or overlap).

K. Diagnostic Program: A software test program, which is used to detect and report system or peripheral malfunctions and failures. Generally, this system is performed at the initial startup of the system.

L. Direct Digital Control (DDC): Microprocessor based control including Analog/Digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices in order to achieve a set of predefined conditions.

M. Distributed Control System: A system in which the processing of system data is decentralized and control decisions can and are made at the subsystem level. System operational programs and information are provided to the remote subsystems and status is reported back to the Engineering Control Center. Upon the loss of communication with the Engineering Control center, the subsystems shall be capable of operating in a stand-alone mode using the last best available data.

N. Download: The electronic transfer of programs and data files from a central computer or operation workstation with secondary memory devices to remote computers in a network (distributed) system.

O. DXF: An AutoCAD 2-D graphics file format. Many CAD systems import and export the DXF format for graphics interchange.

P. Electrical Control: A control circuit that operates on line or low voltage and uses a mechanical means, such as a temperature sensitive bimetal or bellows, to perform control functions, such as actuating a switch or positioning a potentiometer.

Q. Electronic Control: A control circuit that operates on low voltage and uses a solid-state components to amplify input signals and perform control functions, such as operating a relay or providing an output signal to position an actuator.

R. Engineering Control Center (ECC): The centralized control point for the intelligent control network. The ECC comprises of personal computer and connected devices to form a single workstation.

S. Ethernet: A trademark for a system for exchanging messages between computers on a local area network using coaxial, fiber optic, or twisted-pair cables.

T. Firmware: Firmware is software programmed into read only memory (ROM) chips. Software may not be changed without physically altering the chip.

U. FTT-10: Echelon Transmitter-Free Topology Transceiver.

V. GIF: Abbreviation of Graphic interchange format.

W. Graphic Program (GP): Program used to produce images of air handler systems, fans, chillers, pumps, and building spaces. These images can be animated and/or color-coded to indicate operation of the equipment.

X. Graphic Sequence of Operation: It is a graphical representation of the sequence of operation, showing all inputs and output logical blocks.

Y. I/O Unit: The section of a digital control system through which information is received and transmitted. I/O refers to analog input (AI, digital input (DI), analog output (AO) and digital output (DO). Analog signals are continuous and represent temperature, pressure, flow rate etc, whereas digital signals convert electronic signals to digital pulses (values), represent motor status, filter status, on-off equipment etc.

Z. I/P: Internet Protocol-global network, connecting workstations and other host computers, servers etc. to share the information.

AA. JPEG: A standardized image compression mechanism stands for Joint Photographic Experts Group, the original name of the committee that wrote the standard.

BB. Local Area Network (LAN): A communication bus that interconnects operator workstation and digital controllers for peer-to-peer communications, sharing resources and exchanging information.

CC. LonMark: An association comprising of suppliers and installers of LonTalk products. The Association provides guidelines for the implementation of the LonTalk protocol to ensure interoperability through Standard implementation.

DD. LonTalk: An open standard protocol developed by the Echelon Corporation that uses a “Neuron Chip” for communication.

EE. LonWorks: Network technology developed by the Echelon Corporation.

FF. Network: A set of computers or other digital devices communicating with each other over a medium such as wire, coax, fiber optics cable etc.

GG. Network Area Controller: Digital controller, supports a family of auxiliary control units and unitary control units, and communicates with peer-to-peer network for transmission of global data.

HH. Network Repeater: A device that receives data packet from one network and rebroadcasts to another network. No routing information is added to the protocol.

II. MS/TP: Master-slave/token-passing.

JJ. Operating system (OS): Software, which controls the execution of computer application programs.

KK. PCX: File type for an image file. When photographs are scanned onto a personal computer they can be saved as PCX files and viewed or changed by a special application program as Photo Shop.

LL. Peripheral: Different components that make the control system function as one unit. Peripherals include monitor, printer, and I/O unit.

MM. Peer-to-Peer: A networking architecture that treats all network stations as equal partners.

NN. PICS: Protocol Implementation Conformance Statement.

OO. UCU: Unitary Control Unit, digital controller, dedicated to a specific piece of equipment, such as VAV boxes, chillers, fan coil units, heat exchangers etc.

1.4 QUALITY ASSURANCE

A. Criteria:

1. The Controls and Instrumentation System Contractor shall be a primary equipment manufacturer-owned branch office that is regularly engaged in the engineering, programming, installation and service of total integrated Facility Management Systems of similar size, scope and complexity to the EEC specified in this Contract. Distributors, manufacturer’s representatives and wholesalers will not be acceptable.
2. Single Source Responsibility of subcontractor: The Contractor shall obtain hardware and software supplied under this Section and delegates the responsibility to a single source controls installation subcontractor. The controls subcontractor shall be responsible for the complete design, installation, and commissioning of the system. The controls subcontractor shall be in the business of design, installation and service of such building automation control systems similar in size and complexity.

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

B. Codes and Standards:
1. All work shall conform to the applicable Codes and Standards.
2. Electronic equipment shall conform to the requirements of FCC Regulation, Part 15, Governing Radio Frequency Electromagnetic Interference, and be so labeled.
3. Peer-to-peer controllers, unitary controllers shall conform to the requirements of UL 916, Category PAZX.

1.5 PERFORMANCE

A. The system shall conform to the following:

1. Dynamic Graphic Display:
   a) The graphics application program shall be supplied as an integral part of the User Interface.
   b) The graphics applications shall include a create/edit function and a runtime function. The system architecture shall support an unlimited number of graphics documents (graphic definition files) to be generated and executed.
   c) The graphics shall be able to display real-time data that is acquired, derived, or entered.
   d) All graphics shall be fully scalable
   e) The graphics shall support a maintained aspect ratio.
   f) Multiple fonts shall be supported.
   g) The graphics shall support unique backgrounds assignable on a per graphic basis.
   h) From the graphics it shall be possible to change values (setpoints) and states in systems controlled equipment within the Web browser interface.
   i) A graphic editing tool shall be provided that allows for the creation and editing of graphic files. The graphic editor shall be capable of performing/defining all runtime binding.
4. Object Scan: All changes of state and change of analog values shall be transmitted over the high-speed network such that any data used or displayed at a controller or work-station will be current.
5. Alarm Response Time: The maximum time from when an object goes into alarm to when it is annunciated at the workstation shall not exceed (10) seconds.
6. Program Execution Frequency: Custom and standard applications shall be capable of running as often as once every (5) seconds. The Contractor shall be responsible for selecting execution times consistent with the mechanical process under control.
7. Performance: Programmable Controllers shall be able to execute DDC PID control loops at a selectable frequency from at least once every five (5) seconds. The controller shall scan and update the process value and output generated by this calculation at this same frequency.

8. Multiple Alarm Annunciations: All workstations on the network shall receive alarms within (5) seconds of each other.
9. Reporting Accuracy: Listed below are minimum acceptable reporting accuracies for all values reported by the specified system:

Measured Variable	**Reported Accuracy**
Space temperature	±0.5 degrees C (±1 degrees F)
Ducted air temperature	±1.0 degrees C [±2 degrees F]
Outdoor air temperature	±1.0 degrees C [±2 degrees F]
Water temperature	±0.5 degrees C [±1 degrees F]
Relative humidity	±2 percent RH
Water flow	±5 percent of full scale
Air flow (terminal)	±10 percent of reading
Air flow (measuring stations)	±5 percent of reading
Air pressure (ducts)	±25 Pa [±0.1 "W.G.]
Air pressure (space)	±3 Pa [±0.001 "W.G.]
Water pressure	±2 percent of full scale *Note 1
Electrical Power	5 percent of reading

Note 1: for both absolute and differential pressure

1.6 WARRANTY

A. Labor and materials for control systems shall be warranted for a period as specified under Warranty in FAR clause 52.246-21.

B. Control system failures during the warranty period shall be adjusted, repaired, or replaced at no cost or reduction in service to the owner. The system includes all computer equipment, transmission equipment, and all sensors and control devices.

C. The on-line support service shall allow the Controls supplier to dial out over telephone lines to monitor and control the facility’s building automation system. This remote connection to the facility shall be within two (2) hours of the time that the problem is reported. This coverage shall be extended to include normal business hours, after business hours, weekend and holidays. If the problem cannot be resolved with on-line support services, the Controls supplier shall dispatch the qualified personnel to the job site to resolve the problem within 24 hours after the problem is reported.

D. Controls and Instrumentation subcontractor shall be responsible for temporary operations and maintenance of the control systems during the

construction period until final commissioning, training of facility operators and acceptance of the project by VA.

E. The BAS Contractor shall have a fully staffed branch facility within a 100-mile radius of the job site supplying complete maintenance and support services on a 24-hour, 7-day-a-week basis.

F. As evidence and assurance of the contractor’s ability to support the Owner's system with service and parts, the contractor must have been in the BAS business for at least the last five (5) years.

G. The Building Automation System architecture shall consist of the products of a manufacturer regularly engaged in the production of Building Automation Systems, and shall be the manufacturer’s latest standard of design at the time of bid.

1.7 SUBMITTALS

A. Submit shop drawings in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.

B. Manufacturer’s literature and data for all components including the following:

1. A wiring diagram for each type of input device and output device including DDC controllers, modems, repeaters, etc. Diagram shall show how the device is wired and powered, showing typical connections at the digital controllers and each power supply, as well as the device itself. Show for all field connected devices, including but not limited to, control relays, motor starters, electric or electronic actuators, and temperature pressure, flow and humidity sensors and transmitters.
2. A diagram of each terminal strip, including digital controller terminal strips, terminal strip location, termination numbers and the associated point names.
3. Control dampers and control valves schedule, including the size and pressure drop.
4. Installation instructions for smoke dampers and combination smoke/fire dampers, if furnished.
5. Control air-supply components, and computations for sizing compressors, receivers and main air-piping, if pneumatic controls are furnished.

6. Catalog cut sheets of all equipment used. This includes, but is not limited to DDC controllers, panels, peripherals, airflow measuring stations and associated components, and auxiliary control devices such as sensors, actuators, and control dampers. When manufacturer's cut sheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted. Each submitted piece of literature and drawings should clearly reference the specification and/or drawings that it supposed to represent.
7. Sequence of operations for each HVAC system and the associated control diagrams. Equipment and control labels shall correspond to those shown on the drawings.
8. Color prints of proposed graphics with a list of points for display.
9. Furnish PICS for each BACNET compliant device.

C. Product Certificates: Compliance with Article, QUALITY ASSURANCE.

D. As Built Control Drawings:
1. Furnish three (3) copies of as-built drawings for each control system. The documents shall be submitted for approval prior to final completion.
2. Furnish one (1) stick set of applicable control system prints for each mechanical system for wall mounting. The documents shall be submitted for approval prior to final completion.
3. Furnish one (1) CD-ROM in CAD DWG and/or .DXF format for the drawings noted in subparagraphs above.

E. Operation and Maintenance (O/M) Manuals):
1. Submit in accordance with Article, INSTRUCTIONS, in Specification Section 01 00 00, GENERAL REQUIREMENTS.
2. Include the following documentation:
   a. General description and specifications for all components, including logging on/off, alarm handling, producing trend reports, overriding computer control, and changing set points and other variables.
   b. Detailed illustrations of all the control systems specified for ease of maintenance and repair/replacement procedures, and complete calibration procedures.
   c. One copy of the final version of all software provided including operating systems, programming language, operator workstation software, and graphics software.

d. Complete troubleshooting procedures and guidelines for all systems.
e. Complete operating instructions for all systems.
f. Recommended preventive maintenance procedures for all system components including a schedule of tasks for inspection, cleaning and calibration. Provide a list of recommended spare parts needed to minimize downtime.
g. Licenses, guaranty, and other pertaining documents for all equipment and systems.
h. Training Manuals: Submit the course outline and training material to the Owner for approval three (3) weeks prior to the training to VA facility personnel. These persons will be responsible for maintaining and the operation of the control systems, including programming. The Owner reserves the right to modify any or all of the course outline and training material.

F. Submit Performance Report to Resident Engineer prior to final inspection.

1.8 INSTRUCTIONS

A. Instructions to VA operations personnel: Perform in accordance with Article, INSTRUCTIONS, in Specification Section 01 00 00, GENERAL REQUIREMENTS, and as noted below. Contractor shall also video tape instruction sessions noted below.
1. First Phase: Formal instructions to the VA facilities personnel for a total of 16 hours, conducted sometime between the completed installation and prior to the performance test period of the control system, at a time mutually agreeable to the Contractor and the VA.
2. Second Phase: This phase of training shall comprise of on the job training during start-up, checkout period, and performance test period. VA facilities personnel will work with the Contractor’s installation and test personnel on a daily basis during start-up and checkout period. During the performance test period, controls subcontractor will provide 16 hours of instructions to the VA facilities personnel.
3. The O/M Manuals shall contain approved submittals as outlined in Article 1.7, SUBMITTALS. The Controls subcontractor will review the manual contents with VA facilities personnel during second phase of training.

4. Training by independent or franchised dealers who are not direct employees of the controls supplier will not be acceptable.

1.9 PROJECT CONDITIONS (ENVIRONMENTAL CONDITIONS OF OPERATION)

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

B. The CUs and associated equipment used in controlled environment shall be mounted in NEMA 1 enclosures for operation at 0 to 50 degrees C (32 to 122 degrees F) at a relative humidity of 10 to 90 percent non-condensing.

C. The CUs used outdoors shall be mounted in NEMA 4 waterproof enclosures, and shall be rated for operation at –40 to 65 degrees C (-40 to 150 degrees F).

D. All electronic equipment shall operate properly with power fluctuations of plus 10 percent to minus 15 percent of nominal supply voltage.

E. Sensors and controlling devices shall be designed to operate in the environment, which they are sensing or controlling.

1.10 APPLICABLE PUBLICATIONS

A. The publications listed below form a part of this specification to the extent referenced. The publications are referenced in the text by the basic designation only.

B. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):

Standard 135-04.....BACNET Building Automation and Control Networks

C. American Society of Mechanical Engineers (ASME):

B16.18-01.....Cast Copper Alloy Solder Joint Pressure Fittings.

B16.22-01.....Wrought Copper and Copper Alloy Solder Joint Pressure Fittings.

BPVC-CC-N-04.....Boiler and Pressure Vessel Code

D. American Society of Testing Materials (ASTM):

B32-04.....Standard Specification for Solder Metal

B88-03.....Standard Specifications for Seamless Copper Water Tube

B88M-05.....Standard Specification for Seamless Copper Water Tube (Metric)

B280-03.....Standard Specification for Seamless Copper Tube for Air-Conditioning and Refrigeration Field Service

D2737-03.....Standard Specification for Polyethylene (PE) Plastic Tubing

E. Federal Communication Commission (FCC):

Rules and Regulations Title 47 Chapter 1-2001 Part 15..Radio Frequency Devices.

F. Institute of Electrical and Electronic Engineers (IEEE):

802.3-05.....Information Technology-Telecommunications and Information Exchange between Systems-Local and Metropolitan Area Networks- Specific Requirements-Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access method and Physical Layer Specifications

G. Instrument Society of America (ISA):

7.0.01-1996.....Quality Standard for Instrument Air

H. National Fire Protection Association (NFPA):

70-05.....National Electric Code

90A-02.....Standard for Installation of Air-Conditioning and Ventilation Systems

I. Underwriter Laboratories Inc (UL):

94-06.....Tests for Flammability of Plastic Materials for Parts and Devices and Appliances

294-05.....Access Control System Units

486A/486B-04-.....Wire Connectors

555S-03.....Standard for Smoke Dampers

916-Rev 2-04.....Energy Management Equipment

1076-05.....Proprietary Burglar Alarm Units and Systems

PART 2 – PRODUCTS

2.1 CONTROLS SYSTEM ARCHITECTURE

A. General

1. The Controls Systems shall consist of multiple Nodes and associated equipment connected by industry standard digital and communication network arrangements.
2. The Operator Workstations, Servers and principal network computer equipment shall be standard products of recognized major

manufacturers available through normal PC and computer vendor channels – not "Clones" assembled by a third-party subcontractor.

3. Provide licenses for all software residing on and used by the Controls Systems and transfer these licenses to the Owner prior to completion.
4. The networks shall, at minimum, comprise, as necessary, the following:
   a. Operator Workstations – fixed and portable as required by the Specifications.
   b. Network computer processing, data storage and communication equipment including Servers and digital data processors.
   c. Routers, bridges, switches, hubs, modems, interfaces and the like communication equipment.
   d. Active processing network area controllers connected to programmable field panels and controllers together with their power supplies and associated equipment.
   e. Addressable elements, sensors, transducers and end devices.
   f. Third-party equipment interfaces as required by the Contract Documents.
   g. Other components required for a complete and working Control Systems as specified.

B. The Specifications for the individual elements and component subsystems shall be minimum requirements and shall be augmented as necessary by the Contractor to achieve both compliance with all applicable codes, standards and to meet all requirements of the Contract Documents.

C. Network Architecture
1. The Controls Systems Application network shall utilize an open architecture capable of each and all of the following:
   a. Utilizing standard Ethernet communications and operate at a minimum speed of 10/100 Mb/sec.
   b. Connecting via BACNET with ANSI/ASHRAE Standard 135.
   c. LonMark as per ANSI/EIA 709 (LonWorks) to LonMark FTT-10 transceivers.
2. The networks shall utilize only copper and optical fiber communication media as appropriate and shall comply with applicable codes, ordinances and regulations. They may also utilize digital wireless technologies if required by the VA.

3. All necessary telephone lines, ISDN lines and internet Service Provider services and connections will be provided by the owner.
4. The Controls Contractor shall coordinate IT equipment interfacing with the Data Cabling Systems contractor. This IT equipment shall be provided by the Data Cabling systems contractor directly at that contractor’s cost.

D. Third Party Interfaces:
1. The Controls Systems shall include necessary hardware, equipment and software to allow data communications between the Controls Systems and building systems supplied by other trades.
2. The other manufacturers and contractors supplying other associated systems and equipment will provide their necessary hardware, software and start-up at their cost and will cooperate fully with the Controls Contractor in a timely manner and at their cost to ensure complete functional integration.

E. Servers:
1. Provide Controls Systems Application Server(s) to archive historical data including trends, alarm and event histories and transaction logs.
2. Equip these Server(s) with the same software Tool Set that is located in the Network Area Controllers for system configuration and custom logic definition and color graphic configuration.
3. Access to all information on the Controls Systems Server(s) shall be through the same browser Operator Interface functionality used to access individual nodes. When logged onto a Server the Operator will be able to also interact with any other NAC on the Controls As required for the functional operation of the Controls Systems, the Controls Contractor shall provide all necessary digital processor programmable Server(s). These Server(s) shall be utilized for Controls Systems Application configuration, for archiving, reporting and trending of data, for Operator transaction archiving and reporting, for network information management, for alarm annunciation, for Operator Interface tasks, for Controls Application management and the like. These Server(s) shall utilize IT industry standard data base platforms such as Microsoft SQL Server and Microsoft Data Engine (MSDE) or approved equal.

2.2 NETWORK AREA CONTROLLERS (NAC)

A. (NAC) Network Area Controllers shall be stand-alone, multi-tasking, multi-user, real-time digital processor complete with all hardware, software, and communications interfaces, power supplies. The Controls System shall be designed and implemented entirely for use and operation on the Internet. NACs shall have access to data within the industry standard IT network to the Data Server and other NACs as needed to accomplish required global control strategies.

1. NACs shall provide both standalone and networked direct digital control of mechanical and electrical building system controllers as required by the Specifications. The primary NAC shall support a minimum of [5,000] field points together with all associated features, sequences, schedules, applications required for a fully functional distributed processing operation.
2. NACs shall monitor and report communication status to the Controls Systems Application. The Controls Systems shall provide a system advisory upon communication failure and restoration.
3. All NACs on the network shall be equipped with all software functionality necessary to operate the complete user interface, including graphics, via a Browser connected to the Node on the network or directly via a local port on the NAC.
4. All NAC shall be provided with face mounted LED type annunciation to continually display its operational mode, power and communications.
5. The controllers shall reside on the BACnet Ethernet (ISO 8802-3) local area network and provide Read (Initiate) and Write (Execute) services as defined in Clauses 15.5 and 15.8, respectively of ASHRAE Standard 135, to communicate BACnet objects. Objects supported shall include: Analog input, analog output, analog value, binary input, binary output, binary value, and device.
6. Each NAC shall be provided with the necessary un-interruptible power facilities to ensure its continued normal operation during periods of line power outages of, at minimum, 1-minute duration. Normal functionality shall include all normal software processing, communication with powered field devices and network communications with other powered Controls Systems NAC, Data Servers and OWS. Each NAC shall report its communication status to the Application. The Application shall provide a system advisory upon communication failure and restoration. Each NAC shall retain program, control

algorithms, and setpoint information in non-volatile memory in the event of a power failure, and shall return to normal operation upon restoration of power.

7. Each NAC shall have sufficient memory to support its operating system, database, and program requirements, including the following:
   a. Device and network management.
   b. Data sharing.
   C. Alarm and event management including custom alarm messages for each level alarm for the points noted in the I/O Schedule.
   d. Energy management.
   e. Historical trend data for points specified.
   f. Maintenance report.
   g. Scheduling.
   h. Dial up and network communications.
   i. Manual override monitoring.
8. Each NAC shall support firmware upgrades without the need to replace hardware and shall have a minimum of 15 percent spare capacity of secondary system controllers, point capacity and programming functions.
9. Each NAC shall continuously perform self-diagnostics, communication diagnosis, and provide both local and remote annunciation of any detected component failures, low battery condition; and upon failure shall assume the predetermined failure mode.
10. Each NAC shall monitor the status of all overrides and inform the operator that automatic control has inhibited, and allow the operator to manually override automatic or centrally executed command.
11. Provide the capability to generate and modify the Controls Systems Application software-based sequences, database elements, associated operational definition information and user-required revisions to same at any designated Workstation together with the means to download same to the associated System Controllers.
12. In the event of loss of normal power, there shall be orderly shut down of the controllers to prevent the loss of database or software programming. When power is restored flash memory, battery backup or super capacitor will be automatically loaded into non-volatile flash memory and shall be incorporated for all programming data.

13. Each NAC shall be able to support existing JCI N2 controllers, LONWORKS and BACnet simultaneously.
14. Each NAC shall be able to connect directly to Modbus devices without the use of protocol converters. Point inputs and outputs from the Modbus devices shall have real-time interoperability with BAS software such as schedules, Energy Management, Custom processing programming, Alarm Management, Historical Data, Trend Analysis and Totalization.
15. Each NAC shall be able to support optional I/O boards with configurable UIs, DOs and AOs.
16. Acceptable Systems: Facility Explorer Supervisory Controller model FX-60 by Johnson Controls.

F. Diagnostic Devices (DD):
1. Provide a laptop computer capable of accessing all system data. This device may be connected to any point on the system network or may be connected directly to any digital controller for programming, set-up, and troubleshooting.
2. Laptop computer shall be PC notebook style containing necessary software and hardware required. The PC shall contain as a minimum:
   a. 2.4 GHZ Intel Pentium Processor.
   b. 128MB, 100 MHz RAM.
   c. 60GB Hard Drive.
   d. One-Die 256K L2 Cache.
   e. 3.5 inch, 1.44MB Floppy Disk Drive
   f. 48 X CD RW Drive.
   g. 56K Internal Modem.
   h. 32MB video memory graphics.
   i. Ethernet IP network card.
   j. Operating system compatible with PC Microsoft XP professional listed under Operator Workstation.

G. Electric Outlet: Provide a single phase, 120 VAC electrical receptacles inside or within 2 meters (6 feet) of the NAC and ACU enclosures for use with test equipment.

H. Spare Equipment:
1. Provide spare digital controller (CU) boards and spare I/O boards as required. It shall be possible for trained hospital personnel to replace CU boards and load software via the Laptop computer or the ECC.

2. Provide a minimum of one spare digital controller board of each type and associated parts including batteries to make at least one complete set of DDC control equipment spares.
3. If I/O boards are separate from the CU boards, provide two spare I/O boards for each spare CU board provided above.

2.3 DIRECT DIGITAL CONTROLLER SOFTWARE

A. The software programs specified in this section shall be commercially available, concurrent, multi-tasking operating system and support the use of software application that operates under DOS or Microsoft Windows.

B. All points shall be identified by up to 30-character point name and 16-character point descriptor. The same names shall be used at the operator workstation.

C. All control functions shall execute within the stand-alone control units via DDC algorithms. The VA shall be able to customize control strategies and sequences of operations defining the appropriate control loop algorithms and choosing the optimum loop parameters.

D. All CU’s shall be capable of being programmed to utilize stored default values for assured fail-safe operation of critical processes. Default values shall be invoked upon sensor failure or, if the primary value is normally provided by the central or another CU, or by loss of bus communication. Individual application software packages shall be structured to assume a fail-safe condition upon loss of input sensors. Loss of an input sensor shall result in output of a sensor-failed message at the ECC workstation. Each ACU and RCU shall have capability for local readouts of all functions. The UCUs shall be read remotely.

E. All DDC control loops shall be able to utilize any of the following control modes:
   1. Two position (on-off, slow-fast) control.
   2. Proportional control.
   3. Proportional plus integral (PI) control.
   4. Proportional plus integral plus derivative (PID) control. All PID programs shall automatically invoke integral wind up prevention routines whenever the controlled unit is off, under manual control of an automation system or time initiated program.
   5. Automatic tuning of control loops.

F. Application Software: The CUs shall provide the following programs as a minimum for the purpose of optimizing energy consumption while

maintaining comfortable environment for occupants. All application software shall reside and run in the system digital controllers. Editing of the application shall occur at the operator workstation or via a portable workstation, when it is necessary, to access directly the programmable unit.

2. Economizer: An economizer program shall be provided for VAV systems. This program shall control the position of air handler relief, return, and outdoors dampers. If the outdoor air dry bulb temperature and humidity fall below changeover set point the energy control center will modulate the dampers to provide 100 percent outdoor air. The operator shall be able to override the economizer cycle and return to minimum outdoor air operation at any time.
3. Night Setback/Morning Warm up Control: The system shall provide the ability to automatically adjust set points for this mode of operation.
4. Optimum Start/Stop (OSS): Optimum start/stop program shall automatically be coordinated with event scheduling. The OSS program shall start HVAC equipment at the latest possible time that will allow the equipment to achieve the desired zone condition by the time of occupancy, and it shall also shut down HVAC equipment at the earliest possible time before the end of the occupancy period and still maintain desired comfort conditions. The OSS program shall consider both outside weather conditions and inside zone conditions. The program shall automatically assign longer lead times for weekend and holiday shutdowns. The program shall poll all zones served by the associated AHU and shall select the warmest and coolest zones. These shall be used in the start time calculation. It shall be possible to assign occupancy start times on a per air handler unit basis. The program shall meet the local code requirements for minimum outdoor air while the building is occupied. Modification of assigned occupancy start/stop times shall be possible via operator’s workstation.
5. Event Scheduling: Provide a comprehensive menu driven program to automatically start and stop designated points or a group of points according to a stored time. This program shall provide the capability to individually command a point or group of points. When points are assigned to one common load group it shall be possible to assign variable time advances/delays between each successive start

or stop within that group. Scheduling shall be calendar based and advance schedules may be defined up to one year in advance. Advance schedule shall override the day-to-day schedule. The operator shall be able to define the following information:

a. Time, day.

b. Commands such as on, off, auto.

c. Time delays between successive commands.

d. Manual overriding of each schedule.

e. Allow operator intervention.

6. Alarm Reporting: The operator shall be able to determine the action to be taken in the event of an alarm. Alarms shall be routed to the appropriate workstations based on time and events. An alarm shall be able to start programs, login the event, print and display the messages. The system shall allow the operator to prioritize the alarms to minimize nuisance reporting and to speed operator’s response to critical alarms. A minimum of six (6) priority levels of alarms shall be provided for each point.
7. Remote Communications: The system shall have the ability to dial out in the event of an alarm to workstations and alpha-numeric pagers. The alarm message shall include the name of the calling location, the device that generated the alarm, and the alarm message itself. The operator shall be able to remotely access and operate the system using dial up communications. Remote access shall allow the operator to function the same as local access.
8. Maintenance Management (PM): The program shall monitor equipment status and generate maintenance messages based upon the operators defined equipment run time, starts, and/or calendar date limits. A preventative maintenance alarm shall be printed indicating maintenance requirements based on pre-defined run time. Each preventive message shall include point description, limit criteria and preventative maintenance instruction assigned to that limit. A minimum of 480-character PM shall be provided for each component of units such as air handling units.

2.4 SENSORS (AIR, WATER AND STEAM)

A. Temperature and Humidity Sensors:

1. Electronic Sensors: Provide all remote sensors as required for the systems. All sensors shall be vibration and corrosion resistant for wall, immersion, and/or duct mounting.

a. Temperature Sensors: Thermistor type for terminal units and Resistance Temperature Device (RTD) with an integral transmitter type for all other sensors.
   1) Duct sensors shall be rigid or averaging type as shown on drawings. Averaging sensor shall be a minimum of 1 linear ft of sensing element for each sq ft of cooling coil face area.
   2) Immersion sensors shall be provided with a separable well made of stainless steel, bronze or monel material. Pressure rating of well is to be consistent with the system pressure in which it is to be installed.
   3) Space sensors shall be equipped with set-point adjustment, override switch, display, and/or communication port as shown on the drawings. Match room thermostats, locking cover.
   4) Outdoor air temperature sensors shall have watertight inlet fittings and be shielded from direct sunlight.
   5) Room security sensors shall have stainless steel cover plate with insulated back and security screws.
   6) Wire: Twisted, shielded-pair cable.
   7) Output Signal: 4-20 ma.

b. Humidity Sensors: Bulk polymer sensing element type.
   1) Duct and room sensors shall have a sensing range of 20 to 80 percent with accuracy of ± 2 to ± 5 percent RH, including hysteresis, linearity, and repeatability.
   2) Outdoor humidity sensors shall be furnished with element guard and mounting plate and have a sensing range of 0 to 100 percent RH.
   3) 4-20 ma continuous output signal.

c. Static Pressure Sensors: Non-directional, temperature compensated.
   1) 4-20 ma output signal.
   2) 0 to 5 inches wg for duct static pressure range.
   3) 0 to 0.25 inch wg for Building static pressure range.

C. Chilled Water Flow Meter:
   1. Provide an ONICON Model F-1210 Dual turbine Flow Meter or equal complete with installation hardware necessary to enable insertion and removal of the meter without system shutdown. The flow meter shall be hand-insertable up to 400 psi. The flow meter shall have two contra-rotating axial turbines, with electronic impedance-based

sensing and an averaging circuit to reduce measurement errors due to swirl and flow profile distortion. Wetted metal components shall be nickel plated brass. The maximum operating temperature shall be 280°F, 300°F peak. Each flow meter shall be individually wet calibrated against a primary volumetric standard that is accurate to within 0.1% and traceable to NIST. The manufacturer's certificate of calibration shall be provided with each flow meter. Accuracy shall be within ±0.5% of rate at the calibrated velocity, within ±1% of rate over a 10:1 turndown (3.0 to 30 ft/s) and within ±2% of rate over a 50:1 turndown (from 0.4 to 2.0 ft/s). The flow meter shall include integral analog output(s), 4-20 mA, 0-10V or 0-5V.

D. Steam Flow Meter:

1. Furnish and install an Onicon F-2000 Series or equal Vortex Mass Flow Meter complete with integral density compensation to provide direct mass steam flow output. The flow meter shall calculate mass flow corrected for density with real time calculations based on temperature measured by an integral 1000 ohm platinum RTD, Mass flow inferred from specified steam pressure or calculated externally to the flow meter will not be acceptable. The flow meter shall be sized by the manufacturer for each specific application and installed according to manufacturer's recommendations. Provide a flow straightener to meet the manufacturer's minimum upstream straight pipe run requirement. Provide lateral and horizontal supports as required to minimize vibration at the meter location. Each flow meter shall be individually calibrated at five points from 0-250 ft/s against the manufacturer's flow standards. The manufacturer shall provide a certificate of calibration for each meter. The flow meter shall be programmed by the manufacturer for each specific application and shall be ready to use upon delivery. Mass flow accuracy shall be within ± 1.5% of actual reading over the range of the meter, including all errors associated with velocity measurement, temperature and/or pressure measurement, and density compensation. The meter shall be provided with ANSI class 150 or class 300 flanges as required to meet system requirements. The maximum operating temperature shall be 460° F. The flow meter body shall be constructed of 300 series stainless steel and include a weather-tight NEMA-4 aluminum electronics enclosure. The meter shall display steam mass flow rate and mass flow total with an integral

LCD display and support field programming of all parameters. The meter shall also have integral diagnostics to verify installation conditions and the proper operation of the meter. The meter shall provide a loop-powered 4-20 mA output signal calibrated in direct mass flow rate units for connection to the Central Control System. In addition, an integral pulse output for steam mass flow totalization shall be provided. All outputs shall be linear with mass flow rate.

E. Flow switches:
   1. Shall be either paddle or differential pressure type.
      a. Paddle-type switches (liquid service only) shall be UL Listed, SPDT snap-acting, adjustable sensitivity with NEMA 4 enclosure.
      b. Differential pressure type switches (air or water service) shall be UL listed, SPDT snap acting, NEMA 4 enclosure, with scale range and differential suitable for specified application.

F. Current Switches: Current operated switches shall be self powered, solid state with adjustable trip current as well as status, power, and relay command status LED indication. The switches shall be selected to match the current of the application and output requirements of the DDC systems.

2.6 CONTROL CABLES

As specified in Division 26.

2.7 THERMOSTATS AND HUMIDISTATS

A. Room thermostats controlling heating and cooling devices shall have three modes of operation (heating - null or dead band - cooling). Thermostats for patient bedrooms shall have capability of being adjusted to eliminate null or dead band. Wall mounted thermostats shall have polished or brushed aluminum finish, setpoint range and temperature display and external adjustment:
   2. Electronic Thermostats: Solid-state, microprocessor based, programmable to daily, weekend, and holiday schedules.
      a. Public Space Thermostat: Public space thermostat shall be a platinum sensor and shall not have a visible means of set point adjustment. Adjustment shall be via the digital controller to which it is connected.
      b. Patient Room Thermostats: Platinum sensor with set point adjustment and an indicator.

c. Psychiatric Patient Room Sensors: Electronic duct sensor as noted under Article 2.4.

d. Battery replacement without program loss.

B. Strap-on thermostats shall be enclosed in a dirt-and-moisture proof housing with fixed temperature switching point and single pole, double throw switch.

C. Freezestats shall have a minimum of 300 mm (one linear foot) of sensing element for each 0.093 square meter (one square foot) of coil area. A freezing condition at any increment of 300 mm (one foot) anywhere along the sensing element shall be sufficient to operate the thermostatic element.

D. Room Humidistats: Provide fully proportioning humidistat with adjustable throttling range for accuracy of settings and conservation. The humidistat shall have set point scales shown in percent of relative humidity located on the instrument. Systems showing moist/dry or high/low are not acceptable.

2.9 FINAL CONTROL ELEMENTS AND OPERATORS

A. Fail Safe Operation: Control valves and dampers shall provide "fail safe" operation in either the normally open or normally closed position as required for freeze, moisture, and smoke or fire protection.

B. Spring Ranges: Range as required for system sequencing and to provide tight shut-off.

C. Power Operated Control Dampers (other than VAV Boxes): Factory fabricated, balanced type dampers. All modulating dampers shall be opposed blade type and gasketed. Blades for two-position, duct-mounted dampers shall be parallel, airfoil (streamlined) type for minimum noise generation and pressure drop.

1. Leakage: Maximum leakage in closed position shall not exceed 7 L/S (15 CFMs) differential pressure for outside air and exhaust dampers and 200 L/S/ square meter (40 CFM/sq. ft.) at 50 mm (2 inches) differential pressure for other dampers.
2. Frame shall be galvanized steel channel with seals as required to meet leakage criteria.
3. Blades shall be galvanized steel or aluminum, 200 mm (8 inch) maximum width, with edges sealed as required.
4. Bearing shall be nylon, bronze sleeve or ball type.

5. Hardware shall be zinc-plated steel. Connected rods and linkage shall be non-slip. Working parts of joints shall be brass, bronze, nylon or stainless steel.

D. Operators shall be electric.
   1. See drawings for required control operation.
   2. Metal parts shall be aluminum, mill finish galvanized steel, or zinc plated steel or stainless steel.
   3. Maximum air velocity and pressure drop through free area the dampers:
      a. Smoke damper in air handling unit; 210 meter per minute (700 fpm).
      b. Duct mounted damper; 600 meter per minute (2000 fpm).
      c. Maximum static pressure loss, 50 Pascal (0.20 inches water gage).

E. Smoke Dampers and Combination Fire/Smoke Dampers: Dampers and operators are specified in Section 23 31 00, HVAC DUCTS AND CASINGS. Control of these dampers is specified under this Section.

F. Control Valves:
   1. Valves shall be rated for a minimum of 150 percent of system operating pressure at the valve location but not less than 900 kPa (125 psig).
   2. Valves 50 mm (2 inches) and smaller shall be bronze body with threaded or flare connections.
   3. Valves 60 mm (2 1/2 inches) and larger shall be bronze or iron body with flanged connections.
   4. Brass or bronze seats except for valves controlling media above 100 degrees C (210 degrees F), which shall have stainless steel seats.
   5. Flow characteristics:
      a. Three way valves shall have a linear relation or equal percentage relation of flow versus value position.
      b. Two-way valves position versus flow relation shall be linear for steam and equal percentage for water flow control.
   6. Maximum pressure drop:
      a. Two position steam control: 20 percent of inlet gauge pressure.
      b. Modulating Steam Control: 80 percent of inlet gauge pressure (acoustic velocity limitation).
      c. Modulating water flow control, greater of 3 meters (10 feet) of water or the pressure drop through the apparatus.
      d. Two position water valves shall be line size.

G. Damper and Valve Operators and Relays:

2. Electric damper operator shall provide full modulating control of dampers. A linkage and pushrod shall be furnished for mounting the actuator on the damper frame internally in the duct or externally in the duct or externally on the duct wall, or shall be furnished with a direct-coupled design.

2.11 AIR FLOW CONTROL

A. Airflow and static pressure shall be controlled via digital controller (CUs) with inputs from airflow control measuring stations and static pressure inputs as specified. Controller outputs shall be true analog output signals to variable frequency drives. Pulse width modulation outputs are not acceptable. The CUs shall include the capability to control via simple proportional (P) control, proportional plus integral (PI), proportional plus integral plus derivative (PID), and on-off. The airflow control programs shall be factory-tested programs that are documented in the literature of the control manufacturer.

B. Air Flow Monitors

1. Provide airflow measuring stations in the supply and return fan inlets, and the minimum outside air intake airstream, as indicated on the drawings and as outlined herein and as required to meet the sequence of operations. Installation in the fan inlets and the duct system shall be installed under this section under the supervision of the device manufacturer. The manufacturer shall submit written certification that all devices are installed properly.

2. Fan Inlet Airflow Stations: Provide where indicated or required to meet the sequence of operation, airflow measuring centrifugal or plenum devices of the vortex shedding type, capable of continuously monitoring the airflow volume of the fan served and electronically transmitting a signal linear to the airflow volume. All airflow measuring devices shall be capable of measuring velocity over the full range of 350 to 7000 fpm. Devices shall consist of multiple velocity sensors, supported on probe bars.

Individual airflow sensors shall be of rugged construction, and shall not require special handling during installation. Sensors shall be mounted on support bars as required to achieve an equal area transverse. Units shall be mounted in the throat of the fan inlet bell and shall not interfere with the fan motor, drive or cone. All mounting hardware required shall be furnished by the

system manufacturer. Probe bars shall be mounted in accordance with the manufacturer's instructions.

Velocity sensors shall not be affected by dust, temperature, pressure or humidity. The sensors shall be passive in nature with no active parts within the air stream. The output from individual sensors shall be linear with respect to airflow velocity and shall be capable of sensing airflow in one direction only.

Multiple sensors shall be utilized in accordance with the following recommendations:

Fan Inlet Diameter	Sensors Required
To 24"	4
24" to 52"	8
52" to 72"	12

Velocity measurements from individual sensors shall be summed in the integral, companion transmitter. The transmitter output shall be 4-20 ma, power shall be 24 volts DC or AC provided under this section, and shall be fully isolated from ground. Transmitters shall be calibrated for the appropriate full scale cfm and have built-in cfm display. Measurement system accuracy shall be ∀3.0% of rate with repeatability being 1% or better. Transmitters shall have a turndown of at least ten to one.

Velocity sensing methods other than those specified shall be acceptable provided the basic requirements for linear sensing, turndown, accuracy, materials of construction, and transmitter output are met.

Fan inlet airflow measuring stations shall be Vortek units as manufactured by Tek-Air Systems and provided by Accuspec, Inc. at 203-261-8100, or Air Monitor Corporation as approved equals.

3. The airflow measuring station shall be capable of accurately measuring the rate of flow when positioned in the fan inlet or duct system as shown on the contract drawings (re. location relative to elbows, fans, equipment and other duct fittings and components).
4. Supply and return airflow measuring station shall be mounted in the supply and return fan inlets for VAV systems, unless indicated otherwise.
5. Outside Air Low Velocity Airflow Monitoring System (Use for all outside air flow measurement)

   Fabrication

Model: IAQ-Tek as manufactured by Tek-Air Systems Inc., Danbury, CT - Represented by Accuspec, Inc. Phone: 203-261-8100, Fax: 203-261-1981.

Velocity Sensing Probes:

Large Area Impact Probe:

1) Use: Large area impact probes designed to be mounted in areas where turbulence is expected such as in the discharge of louvers, inside rain hoods, after filter banks, before coils, or upstream of outdoor air intake dampers. Probes shall generate a differential pressure in response to changes in air velocity.
2) Velocity Range: Probe shall operate over the range of 1000 to 75 fpm. Turndown in any specific application shall not exceed eight to one (minimum is 8% of maximum).
3) Quantity: Probes are to be provided in the quantity recommended by the manufacturer for the specific area to be monitored.
4) Mounting: Probes are to be provided with any special hardware required to assure secure mounting. Probes can be mounted to within 6" downstream of the intake louver and as close as 6" upstream from the damper without affecting stated accuracy. Probe shall be mounted to minimize extreme angular velocities. Installer to follow manufacturer’s mounting instructions.
5) Orientation: Probe must be located facing into air stream. Pressure connection barbs must be upright.
6) Material: Kydex - T52000 compound with UL ratings of UL-94-V0 and UL-94-5VB.
7) Pressure Connections: ¼ inch barbed connections shall be provided for high and low pressure sensing.
8) Cleaning: Probes shall be able to withstand periodic wash-down with water. If probes cannot be cleaned in this manner, provide upstream filter assemblies to protect the probes from dirt.
9) Humidity: High levels of water vapor, including entrained rain and fog, shall not damage or otherwise affect the operation of the unit (when mounted per manufacturer’s instructions).

Duct Insertion Probes: TFP's

1) Use: Bar type insertion probes, suitable for traverse mounting in ducts. Probes shall generate a differential pressure in response to changes in air velocity.
2) Velocity Range: 4000 to 200 feet per minute. Turndown in any specific application shall not exceed eight to one (minimum is 8% of maximum).
3) Quantity: Probes are to be provided in the quantity recommended by the manufacturer for the specific area to be monitored.
4) Mounting: Probes shall be mounted in accordance with the manufacturer's recommendations.
5) Orientation: Perpendicular to air stream.
6) Material: Extruded aluminum, anodized.
7) Pressure Connections: ¼ inch compression shall be provided for high and low pressure sensing.
8) Probe Length: 6 to 120 inches as required.

Electronics:

Outdoor Air Transducer:

1) Style: Differential pressure type, high accuracy, complete with auto-zero valve and ambient temperature sensor.
2) Range: Differential pressure range shall be selected for the corresponding air velocity range being measured.
3) Temperature range: Transducer shall be capable of operating over the range of -40 to 120 degrees F without any temperature induced errors including zero or span shift.
4) Environment: Transducer shall be mounted in a sealed NEMA 4 enclosure, suitable for mounting in the outdoor air plenum.
5) Pressure Connections: ¼" barbed connections shall be provided for high and low pressure sensing.
6) Electrical Connections: The manufacturer shall provide a weather tight connection cable with weatherproof Amphenol type connector. Cable shall be plenum rated.
7) Orientation: Vertical.
8) Humidity: Transducer shall be protected from condensation in sensing chamber and connection tubing when transducer

temperature is lower than the dewpoint of the measured air stream (when mounted per manufacturer's instructions).

Monitor Electronics:

1) Style: Microprocessor based electronics including integral display and operator keypad.
2) Function: Receive signals from transducer assembly, calculate outdoor air volume and temperature, display information to user, and transmit information to building automation system.
3) Perform self-diagnostics, and alarm on low outdoor air volume.
4) Display: A 4-line by 20-character alphanumeric LCD operator's display shall be provided and shall be backlit for use in low light areas.
5) Temperature range: Monitor shall be capable of operating over the range of +30 to 110 degrees F
6) Environment: Monitor shall be mounted in a sealed NEMA 4 enclosure, suitable for mounting outdoors if required. Enclosure shall include clear window to allow viewing of monitor display without opening the door.
7) Calculations: Monitor shall perform calculations including: differential pressure to velocity, velocity to volume conversions, and correct for altitude, intake air temperature, transducer auto zero routine, and span shift.
8) Analog Outputs: Monitor shall provide industry standard 4-20mA outputs for corrected volume and outdoor air temperature. Scaling of volume output shall be adjustable by the user. Diagnostic functions shall be provided to assist in troubleshooting connections.
9) Contact Outputs: A SPDT contact shall be available which will be normally energized and shall indicate either an alarm condition or unit problem.
10) Setup Wizards: The monitor shall include preprogrammed setup wizards to lead the building automation contractor, test and balance contractor, and/or user through the steps necessary to commission the system.

Source Quality Control

1) Factory Tests: Factory test transducer and monitor for proper operation.

Examination

1) Inspect areas to receive airflow monitors. Notify the Engineer of conditions that would adversely affect the installation or subsequent utilization of the airflow monitors. Do not proceed with installation until unsatisfactory conditions are corrected.

Installation

1) Install airflow probes and transducers at locations indicated on the drawings and as required per the sequence of operation, in accordance with manufacturer's installation instructions.
2) Install monitor electronics at locations indicated on the drawings and in accordance with manufacturer's installation instructions.
3) Install probes such that pressure connections are at the top of the mounted probe. Probes should be installed such that the best coverage or areas being measured can be achieved. Factory assistance shall be available.
4) Install the transducer such that it is located at a slightly higher elevation than the highest probe's ports. Transducer shall be mounted so that the pressure connections are on the bottom of the enclosure. Connecting tubing should be pitched downward and away from the transducer so that any accumulated moisture can drain back towards the probe. Tubing should be installed so that there are no pockets where moisture might accumulate.
5) Cable connecting the transducer and monitor shall be installed in a neat and workmanlike manner. Penetrations through the air handler walls shall provide some means to prevent chafe.

System Static Totalizer (SST) and Static Pressure Sensors:

Provide for each VAV supply fan system multiple point, non-pulsating, system static sensing units installed where indicated in the supply ducts and where called for in the sequences of operation. The system static sensing unit shall be complete with a parallel cell air directionalizer and multiple point static pressure sensing

section with symmetric sensors and self-averaging manifold, and shall not induce a pressure loss in excess of .075 inches w.g. at 2000 feet minute airflow velocity.

The static sensing unit shall have an accuracy within 1% of actual duct static and be capable of producing a steady, non-pulsating static pressure signal. Static Sensing Unit shall have been manufactured two years and be similar to system static totalizer (SST) as manufactured by Air Monitor Corporation, Santa Rosa, CA or the T-SPP 7100 duct averaging sensor (aluminum) as manufactured by Tek-Air Systems or approved equal.

C. Static Pressure Measuring Station:

1. Static Pressure Control:

a. Systems shall consist of one or more static pressure sensors and transmitters along with relays or auxiliary devices as required for a complete functional system. The span of the transmitter shall not exceed two times the design static pressure at the point of measurement. The output of the transmitter shall be true representation of the input pressure with plus or minus 25 Pascal (0.1 inch) W.G. of the true input pressure.

1) Static pressure sensors shall have the same requirements as Airflow Measuring Devices except that total pressure sensors are optional, and only multiple static pressure sensors positioned on an equal area basis connected to a network of headers are required.

2) For systems with multiple major trunk supply ducts, furnish a static pressure transmitter for each trunk duct. The transmitter signal representing the lowest static pressure shall be selected and this shall be the input signal to the CU.

3) The CU shall receive the static pressure transmitter signal and CU shall provide a control output signal to the supply fan capacity control device. The control mode shall be proportional plus integral (PI) (automatic reset) and where required shall also include derivative mode.

4) In systems with multiple static pressure transmitters, provide a switch located near the fan discharge to prevent excessive pressure during abnormal operating conditions.

E. Airflow Synchronization:

1. Systems shall consist of an air flow measuring station for each supply and return duct, the CU and such relays, as required to provide a complete functional system that will maintain a constant flow rate difference between supply and return air to an accuracy of ±10%. In systems where there is no suitable location for a flow measuring station that will sense total supply or return flow, provide multiple flow stations with a differential pressure transmitter for each station. Signals from the multiple transmitters shall be added through the CU such that the resultant signal is a true representation of total flow.
2. The total flow signals from supply and return air shall be the input signals to the CU. This CU shall track the return air fan capacity in proportion to the supply air flow under all conditions.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Examine project plans for control devices and equipment locations; and report any discrepancies, conflicts, or omissions to Resident Engineer for resolution before proceeding for installation.
2. Work Coordination: GENERAL CONDITIONS.
3. Install equipment, wiring /conduit parallel to or at right angles to building lines.
4. Install all equipment in readily accessible locations. Do not run conduit concealed under insulation or inside ducts.
5. Mount control devices, tubing and conduit located on ducts and apparatus with external insulation on standoff support to avoid interference with insulation.
7. Run wire connecting devices on or in control cabinets parallel with the sides of the cabinet neatly racked to permit tracing.
8. Install equipment level and plum.

C. Electrical Wiring Installation:

1. Install conduits and wiring in accordance with Specification Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS.
2. Install signal and communication cables in accordance with Specification Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW).
3. Install conduit and wiring between operator workstation(s), digital controllers, electrical panels, indicating devices, instrumentation,

miscellaneous alarm points, thermostats, and relays as shown on the drawings or as required under this section. All wiring shall be installed in conduits.

4. Install all electrical work required for a fully functional system and not shown on electrical plans or required by electrical specifications. Where low voltage power is required, provide suitable transformers.
5. Install all system components in accordance with local Building Code and National Electric Code.
   a. Splices: Splices in shielded and coaxial cables shall consist of terminations and the use of shielded cable couplers. Terminations shall be in accessible locations. Cables shall be harnessed with cable ties.
   b. Equipment: Fit all equipment contained in cabinets or panels with service loops, each loop being at least 300 mm (12 inches) long. Equipment for fiber optics system shall be rack mounted, as applicable, in ventilated, self-supporting, code gauge steel enclosure. Cables shall be supported for minimum sag.
   c. Cable Runs: Keep cable runs as short as possible. Allow extra length for connecting to the terminal board. Do not bend flexible coaxial cables in a radius less than ten times the cable outside diameter.
   d. Use vinyl tape, sleeves, or grommets to protect cables from vibration at points where they pass around sharp corners, through walls, panel cabinets, etc.
6. Conceal cables, except in mechanical rooms and areas where other conduits and piping are exposed.
7. Permanently label or code each point of all field terminal strips to show the instrument or item served. Color-coded cable with cable diagrams may be used to accomplish cable identification.
8. Grounding: ground electrical systems per manufacturer’s written requirements for proper and safe operation.

D. Install Sensors and Controls:

1. Temperature Sensors:
   a. Install all sensors and instrumentation according to manufacturer’s written instructions. Temperature sensor locations shall be readily accessible, permitting quick replacement and servicing of them without special skills and tools.

b. Calibrate sensors to accuracy specified, if not factory calibrated.
c. Use of sensors shall be limited to its duty, e.g., duct sensor shall not be used in lieu of room sensor.
d. Install room sensors permanently supported on wall frame. They shall be mounted at 1.5 meter (5.0 feet) above the finished floor.
e. Mount sensors rigidly and adequately for the environment within which the sensor operates.
f. Sensors used in mixing plenum, and hot and cold decks shall be of the averaging of type. Averaging sensors shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip.
g. All pipe mounted temperature sensors shall be installed in wells.
h. All wires attached to sensors shall be air sealed in their conduits or in the wall to stop air transmitted from other areas affecting sensor reading.
i. Permanently mark terminal blocks for identification. Protect all circuits to avoid interruption of service due to short-circuiting or other conditions. Line-protect all wiring that comes from external sources to the site from lightning and static electricity.

2. Pressure Sensors:
   a. Install duct static pressure sensor tips facing directly downstream of airflow.
   b. Install high-pressure side of the differential switch between the pump discharge and the check valve.
   c. Install snubbers and isolation valves on steam pressure sensing devices.
3. Actuators:
   a. Mount and link damper and valve actuators according to manufacturer’s written instructions.
   b. Check operation of damper/actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed position.
   c. Check operation of valve/actuator combination to confirm that actuator modulates valve smoothly in both open and closed position.

4. Flow Switches:
   a. Install flow switch according to manufacturer’s written instructions.
   b. Mount flow switch a minimum of 5 pipe diameters up stream and 5 pipe diameters downstream or 600 mm (2 feet) whichever is greater, from fittings and other obstructions.
   c. Assure correct flow direction and alignment.
   d. Mount in horizontal piping-flow switch on top of the pipe.

E. Installation of Network:
   1. Ethernet:
      a. The network shall employ Ethernet LAN architecture, as defined by IEEE 802.3. The Network Interface shall be fully Internet Protocol (IP) compliant allowing connection to currently installed IEEE 802.3, Compliant Ethernet Networks.
      b. The network shall directly support connectivity to a variety of cabling types. As a minimum provide the following connectivity: 10 Base 2 (ThinNet RG-58 A/U Coaxial cabling with BNC connectors), 10 Base T (Twisted-Pair RJ-45 terminated UTP cabling).
   2. Echelon:
      a. The ECC shall employ LonTalk communications FTT-10.
      b. Echelon LAN (Flat LON): The ECC shall employ a LON LAN that will connect through an Echelon Communication card directly to all controllers on the FTT-10 LAN.
   3. Third Party Interfaces: Contractor shall integrate real-time data from building systems by other trades and databases originating from other manufacturers as specified and required to make the system work as one system.

F. Installation of Digital Controllers and Programming:
   1. Provide a separate digital control panel for each major piece of equipment, such as air handling unit, chiller, pumping unit etc. Points used for control loop reset such as outdoor air, outdoor humidity, or space temperature could be located on any of the remote control units.
   2. Provide sufficient internal memory for the specified control sequences and trend logging. There shall be a minimum of 25 percent of available memory free for future use.

3. System point names shall be modular in design, permitting easy operator interface without the use of a written point index.
4. Provide software programming for the applications intended for the systems specified, and adhere to the strategy algorithms provided.
5. Provide graphics for each piece of equipment and floor plan in the building. This includes each chiller, cooling tower, air handling unit, fan, terminal unit, boiler, pumping unit etc. These graphics shall show all points dynamically as specified in the point list.

3.2 SYSTEM VALIDATION AND DEMONSTRATION

A. As part of final system acceptance, a System Demonstration is required (see below). Prior to start of this Demonstration, the contractor is to perform a complete Validation of all aspects of the Controls and Instrumentation System.

B. Validation

1. Prepare and submit for approval a Validation Test Plan including Test Procedures for the performance verification tests. Test Plan shall address all specified functions of the Engineering Control Center and all specified sequences of operation. Explain in detail actions and expected results used to demonstrate compliance with the requirements of this specification. Explain the method for simulating the necessary conditions of operation used to demonstrate performance of the system. Test Plan shall include a Test Check List to be used by the Installer’s agent to check and initial that each test has been successfully completed. Deliver Test Plan documentation for the performance verification tests to the owner’s representative 30 days prior to start of performance verification tests. Provide draft copy of operation and maintenance manual with performance verification test.
2. After approval of the Validation Test Plan, Installer shall carry out all tests and procedures therein. Installer shall completely check out, calibrate, and test all connected hardware and software to insure that system performs in accordance with approved specifications and sequences of operation submitted. Installer shall complete and submit Test Check List.

C. DEMONSTRATION

1. System operation and calibration to be demonstrated by the Installer in the presence of the Architect or Owner's representative on random samples of equipment as dictated by the Owner’s representative.

Should random sampling indicate improper commissioning, the owner reserves the right to subsequently witness complete calibration of the system at no addition cost to the owner.

2. Demonstrate to authorities that all required safeties and life safety functions are fully functional and complete.
3. Make accessible , personnel to provide necessary adjustments and corrections to systems as directed by balancing agency.
4. The following witnessed demonstrations of field control equipment shall be included:
   b. Observe HVAC systems in shut down condition. Check dampers and valves for normal position.
   c. Test application software for its ability to communicate with digital controllers, operator workstation, and uploading and downloading of control programs.
   d. Demonstrate the software ability to edit the control program off-line.
   e. Demonstrate reporting of alarm conditions for each alarm and ensure that these alarms are received at the assigned location, including operator workstations.
   f. Demonstrate ability of software program to function for the intended applications-trend reports, change in status etc.
   g. Demonstrate via graphed trends to show the sequence of operation is executed in correct manner, and that the HVAC systems operate properly through the complete sequence of operation, e.g., seasonal change, occupied/unoccupied mode, and warm-up condition.
   h. Demonstrate hardware interlocks and safeties functions, and that the control systems perform the correct sequence of operation after power loss and resumption of power loss.
   i. Prepare and deliver to the VA graphed trends of all control loops to demonstrate that each control loop is stable and the set points are maintained.
   j. Demonstrate that each control loop responds to set point adjustment and stabilizes within one (1) minute. Control loop trend data shall be instantaneous and the time between data points shall not be greater than one (1) minute.

3.3 SEQUENCE OF OPERATION

A. AHU-1: Variable Air Volume with Energy Recovery Wheel – Nursing Home

1. When supply air fan (SF-1) is energized, its related return air fan (RF-1), exhaust fan (EF-1) and energy recovery wheel are interlocked to start on a time delay.
   Smoke dampers shall open and damper end switches will permit fans to start.
2. When the unit is started, normally closed minimum outside air damper and exhaust air damper shall open. Normally open return air damper remains open and normally closed relief air damper and maximum outside air damper remain closed.
3. Manual reset freeze detection thermostats on the entering side of the cooling coil shall stop the supply fan at low temperature of 38°F and annunciate alarm at ECC.
4. After AH-1 is started, an air flow control system modulates open the supply air fan (SF-1) variable frequency drive (VFD) to maintain supply air static pressure requirements with high pressure override protection.
5. Upon supply air fan shutdown, the supply and return fan VFD’s are controlled to zero speed.
6. When energized, the energy recovery wheel rotates continuously. The speed of rotation varies by means of a VFD and a temperature controller. In winter operation, a thermostat located in the outdoor air duct and another downstream of the heat exchanger controls the speed. As the temperature rises above the setpoint of OA, the wheel slows down. As the temperature drops below the downstream setpoint, the wheel speeds up. In summer operation, the control changes automatically, causing the wheel to rotate at full speed whenever the room air temperature is cooler than the outdoor air temperature.
   A temperature controller with its sensing element located in the AH-1 discharge duct functions to control the pre-heating coil valve, the maximum outside air, relief air and return air dampers and the chilled water coils 2-way valve in sequence to maintain a constant discharge temperature of 59°F or as selected. Discharge temperature is capable of remote adjustment at the ECC. In addition, provide outside air reset of discharge air temperature from 59°F to 55°F as outside temperature varies from 40°F to 60°F, via manual selection by operator at ECC.

7. Enthalpy controls function to allow use of outside air for cooling when the enthalpy of the outside air is less than the enthalpy of the return air. A manual select switch and automatic controls allow the enthalpy to be overridden at the ECC.
8. A return air humidity controller set at 35% RH modulates the clean steam generator humidifier steam supply valve to maintain a return air relative humidity of 35%. A high limit relative humidity discharge controller set at 90% RH overrides if the discharge air RH exceeds 90% RH. Humidifier valve closes when supply fan is de-energized. The steam valve shuts off the steam supply to the humidifier when outside air temperature exceeds 60°F.
9. If smoke is detected in the supply or return ductwork by AC-1's duct-mounted smoke detectors, the supply and return fans (SF-1 and RF-1) are de-energized and the smoke damper shall close. All duct-mounted smoke dampers in AC-1 duct system are also closed.
10. Supply Fan Static Pressure Control:
    a. A static pressure transmitter in the fan discharge and a second static pressure transmitter located 2/3 downstream in the supply duct shall be used as input to a Proportional and Integral control algorithm in the ECC. The supply fan speed shall be modulated through the variable frequency drive (VFD) to maintain a constant fan discharge static pressure. The fan discharge static pressure shall be raised or lowered to maintain a minimum duct static pressure at the second pressure transmitter.
11. Return Fan Tracking Control: Supply and return air CFM as measured at air flow measuring stations at the supply and return fans, shall be input to the ECC. The return fan speed shall be modulated through its VFD to maintain a net volume difference (adjustable) between supply and return air volume. The volume difference shall be the difference between the supply and return air CFM as required based on the air balance and shall be fully adjustable through the ECC.
12. Minimum Outside Air Volume Control: As the supply and return air volumes are reduced the ECC shall modulate exhaust, return and outside O.A.I. dampers to maintain a fixed minimum outside air volume. Minimum outside air flow shall be measured by air flow

measuring stations located in the minimum outside air stream. At the BAS operator's option, minimum outside air volume shall be switched from a fixed minimum cfm (adjustable) to demand ventilation control.

Under demand ventilation control, the amount of minimum outside air shall be varied and shall be set as required to maintain the difference between carbon dioxide (CO2) level in return air and the outside air CO2 level as measured by a sensor located outside the building, below its differential setpoint of 700 ppm (adjustable). While providing demand ventilation control, the minimum outside air cfm shall not exceed the design setpoint level (adjustable) and shall not go lower than a low limit setpoint cfm equal to the difference between the supply and return fan cfm (adjustable).

At the end of each startup, warm up or cool down, the system shall operate for one hour with a pre-set fixed minimum outside air before allowing CO2 demand ventilation control. (This will allow for purge of the space and self-calibration of CO2 sensors prior to occupancy.)

13. A pressure controller in the relief exhaust duct controls the relief exhaust air damper to relieve return air as return air damper modulates closed and static pressure increases.
14. Provide pressure control and sensor in relief exhaust duct that shall speed up return fan VFD to maintain return/exhaust pressure slightly positive, to prevent cold air from being pulled in through exhaust damper.
15. Pre-Heating Coil Low Limit Control: When supply fan is on, pre-heating coil discharge sensor shall act as a low limit, and overcall the fan discharge temperature control to gradually close outside air damper and open heating coil valve, if pre-heating coil discharge temperature drops below its setting of 45°F.

    When supply fan is off, outside air dampers shall close and pre-heating coil valve shall remain under control of pre-heating coil discharge sensor to maintain 45°F adjustable.

B. AHU-2: Variable Air Volume System: Nursing Home

1. The supply air fan (SF-2) is energized and its related return air fan (RF-2), exhaust fan (EF-2) are interlocked to start on a time delay.

2. When the supply fan is energized, the DDC/ECC controls will be energized. Normally closed minimum outside air damper fully opens, normally open return air damper remains open and normally closed relief air damper and maximum outside air damper remain closed. Supply and return smoke dampers shall open and damper end switches shall permit fans to start.
3. Manual reset freeze detection thermostats on the entering side of the cooling coil functions to stop the supply fan and alarms at ECC, on a drop in temperature below setpoint of 38°F (adjustable).
4. After AH-2 is started, the supply air fan (SF-2) variable frequency drive (VFD) modulates to maintain a constant static pressure requirement, with high pressure override protection.
5. Upon supply air fan shutdown, the supply and return fan VFD’s shall be controlled to zero speed.
6. A temperature controller with its sensing element located in the AH-2 discharge duct, functions to control the heating coil steam valve; the maximum outside air and return air and relief air dampers and the chilled water coil 2-way valve in sequence to maintain a constant discharge temperature of 59°F or as selected at the local temperature control panel. Discharge temperature is capable of remote adjustment from ECC.
   In addition, provide outside air reset of discharge air temperature from 59°F to 55°F as outside air temperature varies from 40°F to 60°F, via manual selection by operator at BMS.
7. Enthalpy controls function to allow use of outside air for cooling when the enthalpy of the outside air is less than the enthalpy of the return air. A manual select switch and automatic controls allow the enthalpy cycle to be overridden both locally and remotely at ECC.
8. A return air humidity controller set at 35% RH modulates the clean steam generator humidifier steam supply valve to maintain a return air relative humidity of 35%. A high limit relative humidity discharge controller set at 90% RH overrides if the discharge air RH exceeds 90%. RH humidifier valve closes when supply fan is deenergized. The steam valve shuts off steam supply to humidifier when outside air temperature exceeds 60°F.

9. If smoke is detected in the supply or return ductwork by AC-2's duct-mounted smoke detectors, the supply and return fans de-energize and smoke damper closes. All duct-mounted smoke dampers in AH-2 duct system close.
10. Supply Fan Static Pressure Control:
    a. A static pressure transmitter in the fan discharge and a second static pressure transmitter located 2/3 downstream in the supply duct shall be used as input to a Proportional and Integral control algorithm in the ECC. The supply fan speed shall be modulated through the variable frequency drive (VFD) to maintain a constant fan discharge static pressure. The fan discharge static pressure shall be raised or lowered to maintain a minimum duct static pressure at the 2nd pressure transmitter. The fan discharge static pressure sensor shall not be located in the fan discharge plenum.
11. Return Fan Tracking Control: Supply and return air CFM as measured at air flow measuring stations at the supply and return fans, shall be input to the ECC. The return fan speed shall be modulated through its VFD to maintain a net volume difference (adjustable) between supply and return air volume. The volume difference shall be the difference between the supply and return air CFM as required based on the air balance and shall be fully adjustable through the ECC.
12. Minimum Outside Air Volume Control: As the supply and return air volumes are reduced the ECC shall modulate exhaust, return and minimum outside O.A.I. dampers to maintain a fixed minimum outside air volume. Minimum outside air flow shall be measured by air flow measuring stations located in the minimum outside air stream. At the ECC operator's option, minimum outside air volume shall be switched from a fixed minimum cfm (adjustable) to demand ventilation control.

    Under demand ventilation control, the amount of minimum outside air shall be varied and shall be set as required to maintain the difference between carbon dioxide (CO2) level in return air and the outside air CO2 level as measured by a sensor located outside the building, below its differential setpoint of 700 ppm (adjustable). While providing demand ventilation control, the

minimum outside air cfm shall not exceed the design setpoint level (adjustable) and shall not go lower than a low limit setpoint cfm equal to the difference between the supply and return fan cfm (adjustable).

At the end of each startup, warm up or cool down, the system shall operate for one hour with a pre-set fixed minimum outside air before allowing CO2 demand ventilation control. (This will allow for purge of the space and self-calibration of CO2 sensors prior to occupancy.)

13. A pressure controller in the relief exhaust air duct controls the relief air damper (EAD-4) to relieve return air as return air damper modulates closed and static pressure increases.
14. Provide pressure control and sensor in relief exhaust duct that shall speed up return fan VFD to maintain return/exhaust pressure slightly positive, to prevent cold air from being pulled in through exhaust damper.
15. Heating Coil Low Limit Control: When supply fan is on, pre-heating coil discharge sensor shall act as a low limit, and overcall the fan discharge temperature control to gradually close outside air damper and open heating coil valve, if pre-heating coil discharge temperature drops below its setting of 45°F. When supply fan is off, outside air dampers shall close and pre-heating coil valve shall remain under control of pre-heating coil discharge sensor to maintain 45°F adjustable.

C. AHU-26, 28 and 29, Dual Duct System – Main Hospital Building 100

1. When the supply fan is energized, it will start at minimum speed. Upon proof of supply fan, the return fan will be started at minimum speed. Any associated exhaust fans will start and the control system will operate in occupied mode.
2. For AHU shutdown, the return fan will be de-energized first, then the supply fan will be de-energized. When the supply fan is de-energized, the outdoor air and relief air damper will close and the return air damper will open.

   Any exhaust fan associated with the air handler supply fan will be started and stopped with the supply fan as required.

   Those units serving patient areas will operate continuously, while all others are programmed with occupancy schedules defining occupied and unoccupied times (time of day, day of the week).

3. Occupied Mode
   a. Fan operation: Fans will run continuously in the occupied mode. The fans will not stop until the start of an unoccupied mode.
   b. Global Economizer Enable: AHU outdoor air dry bulb economizer cycle will be enabled when the outside air dry bulb temperature is less than 75°F (adjustable).
   c. Outdoor Air Enthalpy Economizer Cycle: When the outdoor air enthalpy is less than the return air enthalpy, the max outdoor damper and return air dampers will modulate beyond the minimum setting to reduce the cold deck cooling load. When the outdoor enthalpy is greater than the return air enthalpy, the max outdoor damper will close, air dampers will modulate to the minimum outdoor air position.
   d. Cooling Coil Valve: The valve will modulate to maintain a cold deck temperature setpoint (adjustable). The cold deck temperature will be reset when appropriate to achieve energy conservation based on outdoor air temperature, reference space temperatures, fan speed and occupancy.
   e. Heating Coil Valve: The valve will modulate to maintain a hot deck temperature setpoint (adjustable). The hot deck temperature will be reset when appropriate to achieve energy conservation based on outdoor temperature, reference space temperatures, fan speed and occupancy. Hot deck temperature reset from 75°F to 95°F as outside air temperature varies from 70°F to 20°F.
   f. Duct Static Pressure Control: Static pressure will be measured in the supply air duct by two (2) static pressure transducers. The supply fan speed will modulate via the VFD to maintain a minimum static pressure setpoint as VAV dampers throttle to satisfy space requirements. Return fan speed will also modulate in response to the static pressure setpoint to maintain proper air distribution with the space.
   g. Minimum Outside Air Volume Control: As the supply and return air volumes are reduced, the ECC shall modulate exhaust, return and minimum outside OAI dampers to maintain a fixed minimum outside air volume. Minimum outside air

flow shall be measured by air flow measuring stations located in the minimum outside air stream. At the ECC operator's option, minimum outside air volume shall be switched from a fixed minimum cfm (adjustable) to demand ventilation control.

h. Outside Air Ventilation/Carbon Dioxide Control: The minimum quantity of outside air brought into the system will be overridden and increased when the return air CO_2 levels exceed a high limit of 700 parts per million (adjustable) above the outside air CO_2 level. A single CO_2 sensor located in the discharge of the return fan will be used to determine the return air CO_2 level. The minimum outdoor air intake damper, relief damper and return air damper will modulate to maintain return air CO_2 levels at less that 700 parts per million (adjustable). The CO_2 control of outdoor air intake will be overridden by the outdoor air dry bulb economizer control to allow more outdoor air to be used by the system for cooling purposes, when appropriate. Upon failure or removal of the CO_2 sensor, the outside air intake damper position will be controlled by the outdoor air enthalpy economizer cycle above.

i. Termination of occupied mode will occur based on the time of day and day of the week.

j. The preheat coil valve: The preheat medium pressure steam valve will modulate to maintain preheat coil discharge temperature setpoint of 45°F (adjustable). If preheat coil discharge temperature falls below 35°F (adjustable) an alarm will annunciate on ECC operator's work station (OWS).

k. Humidification Control

With humidification activated through the EMS system and the air handler is on, as indicated from supply fan current switch, the humidification system shall be activated. The clean steam generator medium pressure steam control valve will modulate to maintain return air humidity at setpoint 35% (adjustable).

Should the supply air humidity exceed the supply air high limit humidity sensor setpoint 0f 90% (adjustable), the steam control valve will be modulated closed.
The humidification system shall not be active if outside air temperature is above 60°F (adjustable).

4. Warm-Up/Cool-Down Mode
   a. Optimal Start: Supply and return fans will be started in advance of the start of the occupied period as calculated by a self-adaptive optimal start routine. This calculation will be based on the average of the temperature of the area served by the air handler and the outside air temperature. Fan operation will commence early enough to attain occupancy setpoint temperature by the time the space becomes occupied. The window of operation of this mode will be 3 hours (adjustable). The fans will energize as described in the Fan Start/Stop Sequence described above.
   b. The outdoor air/return air damper system will be in the full return air position.
   c. The cooling coil valve will be closed in the warm-up mode. It will be fully open in the cool-down mode.
   d. The heating coil valve will be fully open in the warm-up mode. It will be closed in the cool-down mode.
   e. Termination of warm-up/cool-down mode will occur when the return air temperature of the areas served by the air handler reaches setpoint.
5. Unoccupied Mode
   a. In unoccupied mode, the supply and return fans will be cycled based on the temperature of the areas served by the air handler (determined by space temperature sensors). Fans will operate to maintain an unoccupied duct static pressure setpoint (adjustable) upon activation. Fans will energize in the warm-up mode if any space temperature should fall below the heating setback temperature (adjustable) by 6 degrees. The fans will stop when all the space temperatures rise within 4 degrees of the heating setback temperature. Fans will energize in the cool-down mode if any space temperature would rise above the cooling setup temperature (adjustable) by 6 degrees. The fans will

stop when all temperatures drop within 4 degrees of the cooling setup temperature.

b. The outdoor air/return air damper system will be in the full return air position.

c. In the warm-up mode, the cooling coil valve will be closed. In the cool-down mode, the cooling coil valve will be fully open.

d. In the warm-up mode, the heating coil valve will be fully open. In the cool-down mode, the heating coil valve will be closed.

e. Termination of unoccupied mode will occur based on the time of day and day of the week.

6. Freezestat: The freezestat will be wired so as to physically stop or prevent the start of the supply fan motor and associated return fan motor when activated by low temperature. A low temperature will alarm at the ECC. Reset of the freezestat will be manual at the air handler.

7. Smoke Detection: Whenever smoke is sensed in the return air, the return air smoke detector will signal an alarm at the OWS and the EMS will initiate orderly shutdown of the return fan. If smoke is sensed in the supply duct, the supply air smoke detector will signal an alarm at the OWS and initiate the orderly shutdown of the supply fan.

8. Smoke Dampers: The EMS will alarm at the OWS if the damper end switches do not indicate that the smoke damper is open during supply fan operation or if the end switches indicate that the smoke damper is open when the supply fan is not operational.

D. AH-30 Dual Duct System 100% Outside Air – Main Hospital Building 100

1. The air handling unit supply fan is energized by placing the supply fan HOA switch to the H position or from EMS in Auto position. The associated exhaust fan is energized by placing the exhaust fan HOA switch to the Auto position. The HOA switches are located in the magnetic motor starters adjacent to the air handling units.

2. Whenever the supply fan is energized, the outside air and smoke dampers open. When the dampers are fully open, damper end switches will permit the supply fan to start. The control system shall be enabled.

3. The preheat coil discharge controller modulates the preheat coil medium pressure steam valve to maintain its setpoint.
4. The cooling coil discharge controller modulates the chilled water 2-way valve to maintain cold deck temperature.
5. The hot deck heating coil discharge controller modulates the 2-say medium pressure steam valve to maintain its setpoint. The setpoint is reset by the outdoor air sensor as per hot deck reset schedule below.

Hot Deck Reset Schedule	
OA Temperature	Hot Deck Temperature
20°F	98°F
45°F	85°F
70°F	75°F

6. The exhaust air humidity controller through the high limit discharge humidistat modulates the clean steam generator humidifier steam valve to maintain its setpoint. The humidifier steam valve is closed by de-energizing the supply fan. The humidifier steam valve closes when the outside air temperature exceeds 60°F.
7. If either of the smoke detectors sense smoke in the supply or return duct, the supply and exhaust fans stop.
8. If the preheat coil discharge temperature falls below the setpoint of the freeze detection thermostat, the supply and exhaust fans stop. The freeze detection thermostat is manually reset.
9. The individual space thermostats shall modulate their respective mixing box dampers to maintain setpoint.
10. When the supply fan is de-energized, the outside air and smoke dampers close, the humidifier steam valve closes, the heating coil steam valve remains under control of its controller and the cooling coil chilled water valve closes and the preheat coil face and bypass dampers remain under control of its controller.
11. Pre-Heat / Heat Recovery System
    a. If outside air temperature drops below 50°F (adjustable), the preheat/heat recovery system will be enabled and the lead pump will start. When current switch verifies pump

operation, the heat exchanger medium pressure steam control valve operation will be enabled.

b. The heat exchanger steam valve will modulate to maintain a hot water supply temperature of 80°F (adjustable).

c. When the system is enabled and the outside air temperature is above 80°F (adjustable), the steam valve will close, so as not to add heat to the system.

d. The AHU preheat coil 3-way valve shall be controlled from the preheat coil discharge air temperature sensor to maintain 55°F (adjustable). The 3-way valve shall be modulated to bypass the preheat coil on a rise in discharge air temperature to prevent overheating.

e. If the hot water temperature leaving the preheat coil or the hot water temperature leaving the heat recovery coil drops to 38°F (adjustable), the hot water supply temperature shall be raised and/or the heat exchanger steam valve shall be modulated open to prevent freezing temperatures to the exhaust heat recovery coil to prevent frosting of the heat recovery coil.

f. When the outside air temperature rises above 80°F, the preheat coil 3-way valve shall open fully to the coil as to pre-cool the outside air by using cool air from the exhaust air heat recovery coil, in summer.

g. Safeties and Alarms

Upon a failure of the lead pump, an alarm will annunciate at EMS OWS and the standby pump will be started. The lead pump will be automatically alternated on the first day of each month for equal wear.

If the hot water supply temperature remain 10°F above setpoint or 10°F below setpoint for more than 30 minutes, an alarm will annunciate at ECC.

E. Dirty Filter:

1. A differential pressure transmitter shall read the differential pressure drop across the filter and shall alarm at the EMS OWS when the pressure drop exceeds the dirty filter pressure drop setpoint (adjustable) as indicated on filter schedule or as per manufacturer operating instructions.

2. Provide for both pre-filter, after-filter and final filters for all air handling units.

F. Chilled Water BTU Measurements:

1. Provide chilled water flow meter and chilled water supply and return temperature sensors with supply and return temperature sensors with analog inputs into the ECC. The ECC will indicate flow and calculate BTU’s used by the cold deck cooling coil. Provide for all MER’s.

G. Steam Flow Measurements:

1. Provide steam flow meter and steam pressure sensor with analog inputs into the ECC. The ECC will indicate flow and calculate BTU’s used by the air handler in the MER. Provide for all MER’s.

----- END -----