

SECTION 23 09 23

DIRECT-DIGITAL CONTROL SYSTEM FOR HVAC (REV)

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Control devices and systems to provide the functional requirements of these specifications and as shown on the drawings:
 - 1. Direct Digital Control (DDC) of Heating, Ventilating, and Air Conditioning (HVAC) equipment and systems with electronic positioning of valves and dampers.
 - 2. Electronic control of terminal units, fans, heaters, and similar units for control of room conditions.
- B. The project includes the installation of new controls including standalone panels, sensors conduits, wiring etc. The new controls shall be connected to the existing ECC. The existing ECC is a Trane Tracer Summit system. All graphics, databases, programs shall be done on the Trane ECC. The new controls shall be provided and installed by Trane. Programming and graphics can be configured only by Trane certified technicians. The system shall use Bacnet/IP at the higher level of communication and LONTalk at the unit controllers level.
- C. Electrical power to controls: All electrical work required for the operation of the automatic controls system specified herein, shall be included by the controls contractor. This will include but not limited to providing 115 Volts (or other such as 24 Volts DC) to all components, interlocking smoke detectors and dampers to fire alarm system, providing power circuits, etc. All work shall be done in accordance with NFPA.
- D. ECC software information in the specification: The controls contractor shall use all the existing ECC software functions, alarms, graphic and data bases utilities to comply with the contract documents. These functions are described on this specification.
- E. Definitions:
 - 1. 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.

2. Analog: A continuously varying signal value (e.g. temperature, current, velocity)
3. Baud: A Baud 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 = 9600 Baud/sec is 9600 bits/sec if one signal change = 1 bit.
4. Binary: A two-state system where an "on" condition is represented by a high signal level and an "off" condition is represented by a low signal level.
5. Control Wiring: Includes conduit, wire and wiring devices to install interlocks, thermostats, PE and EP switches, and like devices. Includes all wiring from a DDC cabinet to all sensors and points defined in the input/output summary shown on drawings and required to execute the sequence of operation.
6. Digital Controller (CU): A control module which is microprocessor based, programmable by the user, may include I/O data processing functions. There could be more than one type of CU for specific applications. For example, Auxiliary Units (ACU's) for air handling units, unitary control units (UCU's) for VAV boxes, fan coil units, etc., and Remote Control Units (RCU's) for supervising ACU's and UCU's, etc.
7. Distributed Control Panel (DCP): A panel which houses the digital controller (CU), input and output functions, power supplies, relays, transducers, and associated hardware.
8. Direct Digital Control (DDC): A control loop or subsystem in which digital and analog information is received and processed by a microprocessor based system, and digital control signals are generated based on control algorithms and transmitted to field devices in order to achieve a set of predefined conditions.
9. Deadband: A temperature range over which no heating or cooling is supplied i.e. 22-25 °C (72-78 °F), as opposed to a single point changeover or overlap).
10. Diagnostic Program: A software test program which is used to detect and report system or peripheral malfunctions and failures. This test is performed at the initial start up of the system.

11. 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 (ECC). Upon the loss of communication with the EEC, the subsystems shall be capable of operating in a standalone mode using the last best available data. Digital controllers in a system are linked in a communications network composed of one or more levels of area networks (LAN).
12. Down Load: The electronic transfer of programs and data files from a central computer or operator workstation with secondary memory devices, to remote, distributed computers in a distributed system. Transfer is made over the distributed computers in a distributed system. Transfer is made over the distributed system's communication network.
13. Dynamic Control: A process that optimizes operation of HVAC systems (air handling units, converters, chillers, etc.) by increasing and decreasing setpoints or starting and stopping equipment in response to heating and cooling loads of downstream equipment. A requirement of dynamic control is knowing the heating/cooling demand status of downstream equipment, therefore dynamic control requires controllers connected in a communications network.
14. Engineering Control Center (ECC): The centralized control point for the intelligent control network. The ECC includes operator Workstation(s), network communications control. Operator Workstation includes central Operator's personal computer based terminal, keyboard, mouse, printer(s), and any additional peripheral devices required to perform the primary man-machine functions of the ECC.
15. Firmware: Firmware is software programmed into read only memory (ROM) chips. Software may not be changed without physically altering the chip.
16. Graphic Sequence of Operation: A drawing or graphic showing all interlocks and control loop sequences between the input and output points. Graphic sequence of operation is a graphical

representation of the sequence of operation. The graphic sequence of operation will show all inputs, outputs, and logic blocks.

17. Input/Output (I/O): I/O refers to analog inputs (AI), digital inputs (DI), analog output (AO), and digital output (DO) in a digital controller. Inputs from analog sensors (temperature, pressure, flow, humidity, etc.) and digital sensors (motor status, flow switches, switch position, and pulse output devices).
18. Input/Output Unit: The section of a DDC system through which information is received and transmitted.
19. Man-machine Interface: A method by which an operator is capable of communicating with a DDC system. In the case of a computer, the man-machine interface includes: the keyboard, mouse, monitor, and so on. The Man-machine interfacing allows an operator to command, control, monitor, and program the system.
20. Local Area Network (LAN): A communications bus that interconnects digital controllers for peer-to-peer communications. A LAN shall allow sharing of global information, make it possible to apply building wide control strategies, such as peak demand limiting, permit dynamic control strategies, allow coordinated response to alarm conditions, and permit remote monitoring and programming of digital controllers.
21. Operating System (OS): Software which controls the execution of computer application programs.
22. Peripheral: Input/Output unit used to communicate with the computer, digital controllers, and make copies of system outputs. Peripherals include CRT, printer, tape deck, and diskette.
23. Microprocessor: A microprocessor refers to the central processing unit (CPU) that contains all the registers and logic circuitry that make it possible for digital controllers to do computing.
24. Peer-to-Peer: Peer-to-Peer refers to controllers connected on a communications LAN that act independently, as equals, and communicate with each other and pass information which facilitates control.

25. Resolution: Resolution refers to the number of possible states that input value or output can take and is functional of the digital controller I/O circuitry; the A/D converter for input and the D/A converter for output. Sixteen (16) bit resolution has 65536 possible states and eight (8) bit resolution has 256 possible states.
26. Stand-Alone Control: Stand-Alone Control refers to the digital controller being able to perform required climate control and energy management functions without connection to another digital controller or central site computer. Digital controller requirements for stand-alone control are a time clock, a microprocessor, microchip resident control programs, PID control, a communications port for interfacing with and programming the control, firmware for interrogation and programming, and I/O for sensing and effecting control of its control environment.
27. Virtual Point: A virtual point allows transfer of calculated values between software programs, such as duty cycling, enthalpy, etc. This point resides only in software.

1.2 QUALITY ASSURANCE

A. Criteria:

1. Single Source Responsibility of Supplier: The Contractor shall obtain hardware and software supplied under this section and delegate the responsibility to a single source control supplier. The control supplier shall be responsible for the complete installation and proper operation of the system including debugging and calibration of the CU and all software. The control system supplier shall be in the business of design, installation and service of the computerized building environmental control systems similar in size and complexity to the system specified.
2. Equipment and Materials: Equipment and materials shall be cataloged products of manufacturers regularly engaged in production and installation of HVAC control systems. Products shall be manufacturer's latest standard design and have been tested and proven in actual use.
3. The supplier shall 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 to be involved with the supervision, the engineering, and the installation of the system. Information concerning the amount of training and experience shall be included in each resume. The supplier shall maintain local stock of all devices installed on this project. All personnel for this project must have at least five years of experience in their expertise area and at least one year working with the controls manufacturer.

4. Code approval:

- a. Computer based electronic equipment shall confirm to the requirements of FCC part 15, subpart J, for Class A computing devices governing radio frequency electromagnetic interference (EMI) while continuing to operate normally.
- b. All equipment and components shall be listed under UL 916 for Energy Management Systems, UL 864 for Control Units for Fire-Protective Signaling Systems, UL 1076 for Proprietary Burglar Alarm Units and systems, and UL 294 for Access Control Systems Units.
- c. All wiring shall be in accordance with NFPA 70, Articles 725, 760, and 800.

5. All system software and control commands shall support year 2000 and beyond dates for all reporting, control and other system functions. Year 2000 capability may be provided by future software and necessary equipment upgrades. These upgrades must be at no cost to the government, completed in a manner that causes minimum disruption to government operations, and be installed and fully operational no later than mid 1999. The control system submittal shall describe provisions being made to comply with this requirement.

6. The specification covers minimum requirements and are not intended to preclude provision of equipment or methods that exceed the requirement.

B. Performance Tests:

1. Perform pretests and tests in accordance with Article TESTS in Section 01 00 00, GENERAL REQUIREMENTS, and in accordance with Test Plans and Specifications. Submit Test Report including Final Operational Test.

2. Demonstrate to the Resident Engineer that all controls are installed, adjusted, and can perform all functions required by the drawings and specifications. When coordinated with the Resident Engineer demonstration may be performed in conjunction with instructions to VA operations personnel.
3. Final Operational Tests:
 - a. Performance Test Period: Not less than 80 consecutive hours to demonstrate proper functioning of the complete ECC system after complete installation and debugging of the system. Continue test on a day to day basis until the performance standard is met. This test shall be done after complete installation and debugging of the control systems, and before the final inspection of the control system.
 - b. Acceptance Performance Standard: Operation at an average effectiveness level (AEL) of at least 95 percent for the performance test period. Whenever downtime occurs correct defects before resuming test. Failure due to an individual sensor or controller shall not count as system downtime provided that:
 - 1) The system records the fault.
 - 2) The AEL for all sensors and controllers together is at least 95 percent of the test period.
 - c. Equipment Identification: Section 15050, BASIC METHODS AND REQUIREMENTS (MECHANICAL)
4. Final Operational Tests:

Refer to commissioning sections for additional tests and documentations requirements.

1.3 SUBMITTALS

- A. Submit in accordance with Section 01 33 23, SAMPLES AND SHOP DRAWINGS.
- B. Manufacturer's literature and data for all components including the following:
 1. A wiring diagram for each type of input device and each type of output device including 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.
 4. Installation instructions for smoke dampers and combination smoke/fire dampers.
 5. Control air supply components, and sizing computations for compressors, receivers and main air piping.
 6. Catalog cut sheets of all equipment used. This includes, but is not limited to DDC panels, peripherals, sensors, actuators, and dampers.
 7. Proof of availability of specified standards/tested DDC control program submodules.
 8. Flow charts for each sequence of operation.
 9. Catalog cut sheets of air measuring stations used for the volumetric control system. Include as a separate volumetric control section velocity transmitters, static pressure transmitters, and flow chart for sequence of operation.
 10. Explain and describe in a system performance demonstration procedure, the sequence of tests that will be executed to demonstrate that the system performs all specified and proposed functions. Include in the procedure the method by which system accuracy will be demonstrated.
 11. Sequence of operations for each HVAC system and the associated control diagrams. Equipment and control labels shall correspond to those shown on the drawings.
 12. Color prints of proposed graphics with a list of points for display.
 13. Riser diagrams of wiring between central control unit and all control panels.

14. Scaled plan drawings showing routing of LAN and locations of control panels, controllers, routers, gateways, ECC, and larger controlled devices.
 15. Construction details for all installed conduit, cabling, raceway, cabinets, and similar. Construction details of all penetrations and their protection.
- C. Certificates: Compliance with Article, QUALITY ASSURANCE.
- D. Control Drawings: Show all connections between the ECC, HVAC system, and associated devices using simple line diagrams. Show and identify all HVAC equipment and control devices for all the air, water, and steam systems. Equipment and control labels shall correspond to those shown on the drawings.
- E. Devices layout drawings: Prior installation of control devices show on plan drawings the location of control devices including but not limited to sensors, actuators, transmitters and control panels.
- F. 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.
- G. Operation and Maintenance (O/M) Manuals:
1. Submit in accordance with Article, INSTRUCTIONS, in Section 01 00 00, GENERAL REQUIREMENTS and the requirements herein indicated.
 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 and complete calibration procedures.

- c. One copy of the final version of all software 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. Maintenance Instruction: Document all maintenance and repair/replacement procedures. Replacement procedures shall be documented down to the board level. Provide ordering number for each system component, and source of supply. Provide a list of recommended spare parts needed to minimize downtime.
- 3. 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.
 - 4. Licenses, guaranty, and other pertaining documents for all equipment and systems.
 - 5. Refer to the commissioning sections for additional requirements.

1.4 INSTRUCTIONS

- A. Instruction to VA operations personnel: Perform in accordance with Article, INSTRUCTIONS, in Section 01 00 00, GENERAL REQUIREMENTS:
 - 1. First phase: Formal instruction, for a total of 32 hours, conducted sometime between the completed installation and prior to the performance test period, at a time mutually agreeable to the Contractor and the Resident Engineer.
 - 2. Second phase: On the job training during start-up, check-out, and performance test period. On the job training shall consist of facilities personnel working with the Contractor's installation and test personnel on a daily basis. During the performance test period, provide five 8-hour periods of instruction.
 - 3. The O/M Manuals shall contain approved submittals as outlined in Article 1.5, SUBMITTALS, and the controls contractor review the

manual contents during second phase of the training. In addition, provide diagrammatic layouts of the DDC systems specified. The layouts shall show all DDC cabinets, all connected mechanical systems, locations and function of each sensor, actuator, and equipment cut sheets of the entire system. O/M Manual shall contain a detailed description of the systems and subsystems and a complete listing of all software programs required to perform the sequence of operation. O/M Manual shall describe all commands, operating and troubleshooting instructions, and routine maintenance procedures to be used with the system.

1.5 JOB CONDITIONS (Environmental Conditions of Operation)

- A. The ECC and immediate peripheral devices and system support equipment shall be designed to operate in ambient conditions of 65° to 90 °F at a relative humidity of 20 to 80 percent non-condensing.
- B. Remote equipment:
 - 1. The DCP's and all associated equipment shall be designed to operate in ambient conditions of 32 to 140 °F at a relative humidity of 5 to 95 percent non-condensing.
 - 2. Digital controllers (CU's) shall operate properly with power fluctuations of plus 10 percent to minus 15 percent of nominal supply voltage.
 - 3. Sensors and controlling devices shall be designed to operate in the environment which they are sensing or controlling but not less severe than for DCP's.
 - 4. All digital controllers shall be properly mounted and organized in a grounded UL Listed NEMA 1 cabinet (panel). On outdoors, the cabinet shall be NEMA 3R. The cabinet shall protect digital controllers from dust, liquids, or accidental blows. The cabinet shall be stainless steel 304.

1.6 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):
 - 135-01.....BACNET Building Automation and Control Networks

- C. American Society of Mechanical Engineers (ASME):
- B16.18-01.....Cast Copper Alloy Solder Joint Pressure Fittings.
 - B16.22-01.....Wrought Copper and Copper Alloy Solder Joint Pressure Fittings.
- D. American Society of Testing Materials (ASTM):
- B32-02.....Specification for Solder Metal
 - B88-02.....Specifications for Seamless Copper Tube
 - B88M-99.....Specification for Seamless Copper Tube (Metric)
 - B280-02.....Specification for Seamless Copper Tube for Air-Conditioning and Refrigeration Field Service
 - D2737-03.....Specification for Polyethylene Tube
- E. Institute of Electrical and Electronic Engineers (IEEE):
- 802.3-03.....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)
- F. Instrument Society of America (ISA):
- S7.0.01-00.....Quality Standard for Instrument Air
- G. National Fire Protection Association (NFPA):
- 70-05.....National Electric Code
 - 90A-02.....Standard for Installation of Air-Conditioning and Ventilation Systems
- H. Underwriter Laboratories Inc (UL):
- 94-01.....Test for Flammability of Parts and Devices and Appliances
 - 294-01.....Access Control System Units
 - 486A-01.....Wire Connectors and Soldering Lugs for Use with Copper Conductors
 - 486B-01.....Wire Connectors for use with Aluminum Conductors
 - 555S-03.....Leakage Ratings for Dampers for Use in Smoke Control Systems
 - 916-02.....Energy Management
 - 1076-99.....Proprietary Burglar Alarm Units and Systems

1.7 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. All work performed and all material and equipment furnished under this contract shall be free from defects and shall remain so from the moment it is partially accepted until the final acceptance and/or completion date of the construction project and thereafter for a period of one year from the date of acceptance of the entire construction project by the Contracting Officer.
- C. GUARANTY PERIOD SERVICES: Controls and Instrumentation subcontractor shall be responsible for temporary operations, maintenance and repairs of the control systems during the construction period and/or the moment it is partially accepted until the final acceptance and/or completion date of the construction project and thereafter for a period of one year from the date of acceptance of the entire construction project by the Contracting Officer.
- D. Control system failures during the guaranty 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. Contractor shall provide all necessary test equipment, parts and labor to perform required inspection, testing, maintenance and repair on new devises, reused equipment (if any) and system installed under this project.
- E. Service and emergency personnel shall report to the Engineering Office or their authorized representative upon arrival at the hospital and again upon the completion of the required work. A copy of the work ticket containing a complete description of the work performed and parts replaced shall be provided to the COTR or his authorized representative.
- F. Emergency Service:
 - 1. Warranty Period Service: Service other than the preventative maintenance, inspection, and testing shall be considered emergency call-back service and covered under the warranty of the installation during the one-year warranty period, unless the required service is a result of abuse or misuse by the Government. Written notification

shall not be required for emergency warranty period service and the contractor shall respond as outlined in the following sections on Normal and Overtime Emergency Call-Back Service. Warranty period service can be required during normal or overtime emergency call-back service time periods at the discretion of the COTR or his authorized representative.

2. Normal and overtime emergency call-back service shall consist of an on-site response within 2 hours of notification of a system trouble.
3. Normal emergency call-back service times are between the hours of 7:30 a.m. and 4:00 p.m., Monday through Friday, exclusive of federal holidays. Service performed during all other times shall be considered to be overtime emergency call-back service. The cost of all normal emergency call-back service shall be included in the cost of this contract.
4. Overtime emergency call-back service shall be provided for the system when requested by the Government. The cost of all man hours per year of overtime call-back service shall be provided under this contract. The method of calculating overtime emergency call-back hours is based on actual time spent on site and does not include travel time.

PART 2 - PRODUCTS

2.1 DIRECT DIGITAL CONTROL SYSTEM

- A. Provide a DDC system as a distributed control system. The system shall have stand-alone direct digital controllers (CU's), a communications network, and the Engineering Control Center (ECC).
- B. To prevent a single-failure catastrophe, and to minimize the effect of a digital controller failure, multiple CU's shall be provided. Failure of any single controller shall have no effect on other controllers, except where global strategy is involved. The DDC network shall automatically reconfigure on a network break to ensure survivability of global communications among remaining CU's on the network. Failure of the ECC shall have no effect on other controllers, including those involved in global strategies. There could be more than one type of CU for specific applications. For example Auxiliary control units (ACU's) for air handling units shall support, but not necessarily limited to, all the necessary points

inputs and outputs to perform the specified control sequences in a totally stand-alone fashion, or unitary control units (UCU's) for VAV boxes, fan coil units, converters, and chillers, etc. address specific applications pertaining to these equipment. These units shall connect to field sensors and control devices. The other type of digital controller could be a remote control unit (RCU) supervising air handling unit controllers and unitary control units. The remote control units RCU's shall communicate with other RCU's and with the ECC over a local network, and shall provide general purpose control functions, global control functions, and history recording function. The RCU's and their associated control units shall communicate over a dedicated communication circuit. Provide the quantity of digital controllers indicated on the drawings that will perform required climate control.

- C. Separate digital controllers shall be provided where shown on the drawings as minimum requirements at least one CU per mechanical room. Additional CU's may be provided as contractor's option.
- D. Direct digital controllers (CU's) shall be microprocessor based with all hardware, software, and communications interfaces. CU's shall have access to data within the network as needed in order to accomplish required global control strategies. Communication shall not be depended upon the ECC. If communication between RCU's or between and RCU and the ECC is disrupted, remaining CU's shall continue to operate in stand-alone mode. Likewise, if communication between an ACU and it's connected RCU, or between a UCU and its connected RCU is disrupted, remaining CU's shall continue to operate in stand-alone mode. The RCU controllers shall each be either 32 bit or 16 bit microprocessors configured in a true distributed manner where input-output processing is a function of the DDC controller. ACU and UCU controller shall be 8 bit or 16 bit or 32 bit microprocessors as necessary to perform required functions.

Remote "slave" gathering panels are not acceptable:

1. The controller shall be modular and wired in a NEMA 1 enclosed Distributed Control Panel (DCP) complete with all relays digital to analog converters, and terminal strips. If the panel is located outdoors the panel shall be NEMA 3R. RCU's shall have sufficient memory, but not less than 640 kb and a minimum of 20%

spare capacity of its I/O functions. The type of spares shall be in the same proportion as the implemented I/O functions on the panel, but in no case shall there be less than two spare points of each implemented I/O type. The panel I/O functions shall be furnished complete, with no changes or addition necessary to support implementation of space functions. ACU's shall also have a minimum of 10% of its I/O functions as spare capacity.

2. The controllers and I/O function boards shall be designed to operate in the environmental ambient conditions noted in paragraph 1.7B.
3. The system shall utilize EPROM or EEPROM and RAM memory. All DDC algorithms and parameters shall be RAM or EEPROM based for ready access for modification and adjustment. RAM memory shall be provided with 72 hours battery backup minimum. Digital controllers that are downloaded automatically following power fail/restart or that have non-volatile RAM need not have battery back up.
4. Provide hardware resident clock with each central plant/air handling unit and each controller on the highest level local area network (LAN) which shall have its clock backed up by a battery or a capacitor with sufficient capacity to maintain clock operation for a minimum of 72 hours during normal power outage.

E. Input/Output Equipment:

1. Input/Output (I/O) modules shall accept industrial platinum resistance sensors. Analog input resolution shall be 12 bit; 8 bit resolution controllers are not acceptable. Each output point shall be provided with a light emitting diode (LED) which shall indicate status (on-off) of digital outputs. Analog outputs must be true analog for proportional output control. The status and position indication may also be presented on a portable hand held display device. Processor software shall allow for scaling and for calibration of sensor lead length variations to insure display accuracies.
2. The following table indicates the type of sensors and signal that shall be used for input/output to the direct digital controllers. Reference the Hardware section of these specifications for further sensor requirements. Thermistor or thermocouple inputs

are not acceptable for ACU's and RCU's. Thermistors may be used for application specific unitary controllers (UCU's) where any non-linear thermistor characteristic is compensated for in software.

SENSOR/OUTPUT DEVICE	SENSOR RANGE
RTDs w/Transmitters	0420 ma, 0-10VDC
Platinum Element Direct	1000 or 3000 ohm
RTD or Balco Direct	500 or 1000 ohm
E/P Output Transducer	20-103 kPa (3-15 PSI)
Relative Humidity	4-20 ma, 0-10V, 0-1V
Pressure	4-20 ma, 0-10V, 0-1V
Others-i.e. Current, Voltage	4-20 ma, 0-10V

3. The CUs and digital output modules shall be capable of performing two and three state output functions to emulate H-O-A switches and contact closures.

F. UL Listing:

The Control Unit (CU) shall be listed by Underwriter Laboratories per UL 916, UL 876, and UL 1064.

G. Communication Ports:

1. Controller to Controller LAN Communication Ports: Controllers in the building DDC system shall be connected in a communications network. Network may consist of more than one level of area network and one level may have multiple drops. Communication network shall permit sharing between controllers of sensor and control information, thereby allowing execution of dynamic control strategies and coordinated response to alarm conditions. Minimum baud rate for the lowest level LAN shall be 9600 Baud. Minimum baud rate for the highest level LAN shall be 9600 Baud. Minimum baud rate for a DDC system consisting of a signal LAN shall be 9600 Baud.
2. On-Site Interface Ports: Provide a RS-232, RS-485, or RJ-11 communications port for each ACUs and RCUs digital controller that allows direct connection of a computer or PDOT (as defined in para 2.1.G) and through which the controller may be fully interrogated, and for downloading and uploading control programs, modifying programs and program data base, and retrieving or accepting trend reports, messages, and alarms. Controller access

shall not be limited to access through another controller. On-site interface communication ports shall be in addition to the communications port(s) supporting controller to controller communications. Communication rate shall be 9600 Baud minimum.

3. Remote Work Station Interface Port: Provide one additional direct connect computer port in each DDC system for permanent connection of a report operator's work station, unless the workstation is a node on the LAN.

H. Diagnostic Devices (DD):

1. Diagnostic devices are hand held terminals for communication with the direct digital controllers and the ECC.
2. Each Control Unit (CU) and ECC shall be supplied with connections to which maintenance personnel can connect portable diagnostic operators (PDOT's) for data display, setpoint modifications, and reloading and modification of controller programs.

I. Electric Outlet:

Provide a single phase, 120 Vac electrical service outlet inside or within 2 meters (6 feet) of the RCU and ACU enclosures for use with test equipment.

J. Spare Equipment:

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 PPT and the ECC.

1. 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.
2. If I/O boards are separate from the CU boards, provide two spare I/O boards for each spare CU board provided above.

2.2 DIRECT DIGITAL CONTROLLER SOFTWARE

- A. The DDC system shall be a network of independent stand-alone CU's. Each CU shall be capable of full control of its assigned functions as a completely independent unit. The sequence of control shall be written to include control operations (such as temperature and pressure control loops), time event operations, energy management functions (night set back, reset schedules, and optimum start routines), push button overrides, demand limiting, safeties, and emergency conditions:

1. The CU operating system software shall be PROM resident and operate independently of the ECC. The operating system shall provide alarm monitoring and reporting, provide control application packages, and contain built-in automatic diagnostic routines.
 2. After a power failure and upon a power restoration, the system shall provide automatic sequential restart of equipment based on current program time and program requirements without operator invention.
- B. All temperature 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. The VA shall be able to make these changes without having to burn new CU EPROMS, all data file information will be held in EEPROM for ease of access and change. Each CU shall include the following stand-alone functions:
1. Direct Digital Control algorithm and control sequences are to be CU resident and be capable of stand-alone operation independent of the ECC. All DDC programs shall be custom written as required to meet the performance criteria spelled out in the sequence of operation paragraphs for each controlled mechanical system. PID algorithm shall be employed as appropriate to the application and per sequences or operation.
 2. All CU resident DDC programs shall be capable of being enabled or disabled from the ECC. In the enable mode all DDC loops shall be active and output signals shall be routed to the final control elements. In the disable mode all DDC loop calculations shall continue but outputs to actuators shall go to fail safe mode. (When disabled, control outputs shall stay in the same state or position as commanded from the central or until they are manually set to automatic.)
 3. To eliminate integral windup, all PID programs shall automatically invoke integral windup prevention routines whenever the controlled unit is off, under manual control or under control of an EMS or time initiated program.
- C. Default Value Operation:

All CU's shall be capable of being programmed to utilized 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, 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 central control and command station. Each ACU and RCU shall have capability for local readouts of all functions. The UCUs shall be read remotely.

D. Control loops shall be able to utilize any of the following control modes:

1. Two position (on-off, slow-fast)
2. Proportional
3. Proportional plus integral (PI)
4. Proportional plus integral plus derivative (PID)

E. Standard/Tested DDC Control Program Submodules:

1. The following list is typical of standard direct digital control submodules that have been written, factory tested, and successfully used on many projects. Proof shall be included in the submittal that such project applicable programs standard has been written, tested, and successfully used by the contractor on at least five other projects:
 - a. Sequenceable analog output submodule
 - b. Sequenceable two-position output submodule
 - c. Reset main temperature setpoint submodule
 - d. Single zone control submodule
 - e. Humidity control submodule
 - f. Dewpoint and humidity control submodule
 - g. Highest of two sensors control submodule
 - h. Controller with summer-winter changeover submodule
 - i. Three input controller submodule
 - j. Fan static pressure control submodule
 - k. Static pressure control with return fan reset submodule
 - l. Differential temperature control submodule
 - m. Binary step output submodule
 - n. Step and proportional output submodule

- o. Hot water reset submodule
 - p. Mixed air submodule
 - q. Single zone control with heating/cooling submodule
 - r. Single input control with Energy Management Control System (EMCS) submodule flow charts
2. Provide flow charts for each of the project submodule programs at time of submittal.

F. System Diagnostics:

1. System diagnostic software and hardware diagnostic software stored in non-volatile memory shall be provided for the central computer and each remote DCP CU. Each intelligent board within each remote DCP shall independently execute its own cold-start initialization diagnostic routines. These tests shall assure that the board circuitry is operating properly and that the individual boards within the system communicate with each other properly. If any test within the system detects a problem, a message shall be output to the peripheral devices provided the failure is not within the peripheral devices themselves or within the peripheral communication circuitry. Additionally, LED indicators which are visible while the board is operating shall be provided to localize the fault. The LED indicators shall operate in addition to the peripheral device reporting.
2. Cold-start initialization diagnostics shall be initiated by power-up and operator keyboard request. Additional hardware and software shall be provided to continuously monitor on-line system operation and detect system faults.

G. Application Software:

1. Application software programs shall be distributed throughout the CUs in the system. Distributed software resident in CUs shall be provides for stand-alone operating independent of the ECC and to improve system throughout and response time by reducing the workload on the central control. All CUs shall contain software, compatible with ECC software, as necessary for scheduling and controlling resident programs, and for data file management. All energy management sensor failures shall be immediately reported to the operator. Each unique application program shall be capable of being enabled or disabled by the operator from the PPT and the ECC.
2. Provide the following programs as a minimum:
 - a. Optimum Start: Optimum start program shall automatically delay equipment startup based on outdoor temperature, space temperature, and system response to assure that comfort conditions are reached exactly at scheduled occupancy time. The program is to operate in both heating and cooling cycles. An adaptive algorithm is to be employed which will automatically adjust according to past experiences. Algorithm shall be tested and updated every day. The program shall automatically assign longer lead times for weekend and holiday shutdowns. Space temperature input is to be the highest value of zones served in the cooling mode and the lowest of zones served in the heating mode. It shall be possible to assign occupancy start times on a per air handler unit basis. Modification of assigned occupancy start times shall be possible via the central operator's terminal.
 - b. Automatic Restart Programming: Motor in "start" mode shall not restart instantaneously when power is restored after failure. Restart shall be sequenced by the CU network restart program:
 - 1) Automatic restart of preassigned field equipment upon resumption of commercial power: Provide a computer software program that will restart field device in preassigned sequence upon restoration of commercial power. The program shall execute the appropriate sequential

commands to restore the building to a minimal, satisfactory operating condition. The operator shall be able to assigned equipment to be started, on-line, through the keyboard. Indication of commercial power return as well as program initiation shall be displayed and recorded at the printer.

- 2) Automatic restart of preassigned field equipment upon application of emergency power: Provide a computer software program that will restart field devices upon application of emergency and commercial power resumption, and shall execute the appropriate sequential minimal, satisfactory operating condition under emergency power conditions. The operator shall be able to assign equipment to be started, on-line through the keyboard.
- 3) Indication of commercial power failure and emergency power as well as program availability initiation shall be displayed and recorded at the printer. All field cabinet (DCP) power failures shall be printed. A status message shall be printed whenever emergency or commercial power is restored. A hold interval shall be provided before program channel initiation to allow operator intervention.

c. Prevention Maintenance Instruction (PMI) programming: A preventative maintenance alarm shall be printed indicating maintenance requirements based on run time. The log shall include all equipment listed in the ECC schedule that have reached limit criteria of calendar-date (month-day-year) or high accumulation of totalized run-time (for points with start/stop or run status indication). Each PMI message shall include point description, limit criteria and preventative maintenance instruction assigned to that limit. A minimum of 480 character PMI shall be provided for each component of units such as air handling units. All criteria, PMI and reset-to-zero assignments shall be operator programmable, on-line at the keyboard. Stagger initial alarms to distribute maintenance throughout the year. Program initial PM alarms as follows:

- 1) Air handling units and water chillers, run time 2000 hours

- 2) Prefilters, run time 1000, hours, afterfilters, run time 3000 hours
 - 3) Fans and pumps, run time 4000 hours
 - 4) Refrigerators/freezers, converters, cooling tower system, water treatment, calendar time 3 months
 - 5) Emergency generator oil samples, calibration of instrumentation and controls, calendar time 12 months
 - 6) All other, calendar time 4 months
- d. Fire Emergency Programming:
- 1) Upon sensing of smoke the unit fan shall be stopped and smoke dampers (if shown or requested by drawings) shall be closed.
- e. Sensor and Control Devices:
- 1) General: Provide all remote sensing points and instrumentation as required for the systems. All sensors shall have accuracies as stated hereinafter.
 - 2) Field wiring for each digital device shall be two or three conductor No. 18 AWG, or larger twisted sets of copper conductors 300 volts, thermoplastic. When line voltage is present in conduits or wiring trays the insulation on all conductors shall be 600 volts. For multiconductor wire having four or more conductors, wire size shall be not less than No. 20 AWG solid copper.
 - 3) Temperature Sensors:
 - a) Temperature sensors shall be of the resistance type. Thermo-couples may be used but shall be restricted to temperature range of 260 °C (500 °F) and above. Temperature sensors located outdoors shall have sun shields.
 - b) The following shall apply to temperature sensors:
 1. Stem or tip sensitive types.
 2. Sensing elements shall be hermetically sealed.
 3. Stem and tip construction shall be 304 stainless steel, copper, glass, or epoxy.
 4. All external trim material shall be corrosion resistant designed for the intended application.

5. Thermometer wells shall be of bronze, stainless steel, copper, or monel materials. Heat transfer compounds shall be compatible with the sensors. At each sensor location in piping provide a well suitable for a glass stem mercury thermometer.
6. Sensor accuracy: Sensors are only one element in the overall system accuracy to which the CU can respond. That response includes alarm decision, value display, value calculation on which analog values must be multiplied, subtracted, square rooted, etc. As such, the system end-to-end accuracies are herein stated. Sensors that have a tendency to drift with age shall be supplied with self-correction, therefore the following range/accuracies are stated:

<u>Typical Range</u>	<u>Accuracy</u>	<u>Typical Application</u>
0 to 20 deg C (30 to 70 deg F)	plus or minus 0.5 deg C (plus or minus 0.5 deg F)	Chilled Water
Minus 40 to 40 deg C (Minus 50 to 100 deg F)	plus or minus 1.0 deg C (plus or minus 1.2 deg F)	O.A.
Minus 20 to 40 deg C (1 to 100 deg F)	plus or minus 0.5 deg C (plus or minus 0.7 deg F)	Space Temps
10 to 120 deg C (50 to 250 deg F)	plus or minus 1.0 deg C (plus or minus 1.2 deg F)	General Equip
Minus 20 to 260 deg C (0 to 500 deg F)	plus or minus 2.0 deg C plus or minus 3.0 deg F	High Temp HW

7. Sensors for differential temperature readings to be read in BTU (kilojoule) calculations shall be a matched pair with a differential accuracy of plus or minus 0.1 degrees C (0.1 degrees F).

- 4) Differential pressure sensors:
 - a) The entire assembly shall be constructed to shock, vibration and pressure surges of 170 kPa (25 psi) above scale will neither harm the gauge nor affect its accuracy.
 - b) Sensors shall have the following features:
 1. Software adjustable high and low limits.
 2. Suitability for operation in an ambient temperature range of 0 to 60 degrees C (30 to 140 degrees F).
 3. Accuracy within 5 percent of full scale.
 - c) Flow status of fans and pumps, 370 watts (1/2 hp) and larger, shall be proven by differential pressure switches. Provide software resident time delays to prevent false alarms during starting/stopping including printout and application programs.
- 5) Water Flow Rate Sensor and Indicator:
 - a) Sensor shall be insertion turbine type with turbine element, retractor and preamplifier/transmitter mounted on a two-inch full port isolation valve. Design shall be such that the entire assembly may be easily removed or installed as a single unit under line pressure through the isolation valve without interference with process flow. The retracting assembly shall have a calibrated scale to allow precise positioning of the flow element to the required insertion depth within plus or minus 1 mm (0.05 inch). All primary wetted parts shall be constructed of 316 stainless steel, 17-4 stainless steel, and tungsten carbide. Operating power shall be nominal 24 VDC. Local instantaneous flow indicator shall be LED type in NEMA 4 enclosure with 3-1/2 digit display, for wall or panel mounting.
 - b) Performance characteristics:
 1. Ambient conditions, -40 to 60 degrees C (-40 to 140 degrees F), 0 to 100 percent humidity.
 2. Operating conditions, 850 kPa (125 psig), 0 to 120 degrees C (30 to 250 degrees F), 0.15 to 12 m per second (0.5 to 40 feet per second) velocity.

3. Nominal range (turn down ratio), 10 to 1.
 4. Overall accuracy, including linearity and repeatability: plus or minus two percent of reading.
 5. Repeatability, plus or minus 0.25 percent of reading.
 6. Preamplifier mounted on meter shall provide a 4-20 ma divided pulse output or switch closure signal for units of volume or mass per a time base. Signal transmission distance shall be a minimum of 1,800 meters (6,000 feet). Preamplifier for bi-directional flow measurement shall provide a directional contact closure from a relay mounted in the preamplifier.
 7. Pressure loss, maximum 1% of the line pressure in line sizes above 100 mm (4 inches).
 8. Ambient temperature effects, less than 0.005% calibrated span per degree C (degree F) temperature change.
 9. RFI effect - flow meter shall not be affected by RFI.
 10. Power supply effect less than 0.02% of span for a variation of plus or minus 10 percent power supply. Maximum power consumption shall be 1.4 watts or less per flow meter.
- 6) Pressure Differential Switches:
- a) All pressure sensing elements shall be corrosion resistant.
 - b) Pressure sensing elements shall be Bourdon tubes, bellows diaphragm or piezoelectric type.
 - c) Switch type units shall have adjustable set point settings.
 - d) Pressure sensor switches shall be snap action type contacts designed for the application. For logic inputs to the CU's, contacts shall be short radius gold or rhodium plated to insure proper switching for the power logic circuits. When switching other items they shall be suitable for the load.
 - e) Switch type sensor assemblies shall operate automatically and reset automatically when conditions return to normal.

- f) Sensor ratings: Sensors shall have the following pressure and accuracy ratings:
 - 1. Chilled, condenser and hot water sensors shall be rated at 900 kPa (125 psig).
 - 2. Sensors on all steam lines shall be protected by pigtail siphons installed between the sensor and the line, and shall have an isolation valve installed between the sensor and pressure source.
- 7) Relative Humidity Sensors: The sensor shall be an analog precision capacitance type relative humidity detector. The sensing element shall be rated for the relative humidity range designed into the building environmental control system. The sensor shall have a constant accuracy of plus or minus 2.0 percent relative humidity.

2.3 ENGINEERING CONTROL CENTER (ECC) (EXISTING)

- A. The ECC shall function as the primary operator interface (man-machine) device to the distributed control system. As such, it shall be useable by the operator to provide control over the communication system and monitor all connected digital controllers for change of state, change of value, or no respond conditions. The ECC shall contain software that allows it to be used for preparing data bases for any part of the system, for defining system configuration, for adding and deleting points, and for defining control loops. The ECC software shall also provide for historical data storage, archiving of system databases, downloading of data to the DCPs, alarm reporting, trending and other functions not performed by the distributed control systems. Failure of the ECC shall in no way adversely affect the operation of the overall control system.
- B. The system man-machine interface shall be an easy to use, self-guiding, full graphic, menu penetration approach. Key features that shall be included in the interface are as follows:
 - 1. Full English data addressing and presentation
 - 2. Interactive operation and help messages
 - 3. Organization of points into logical groups
 - 4. Fill-in-the-blanks programming
 - 5. On-line data file programming
 - 6. Segregation of information to appropriate terminals

7. Five levels of system access for security (password protection)
8. Pictorial representation of data on color graphic terminals with dynamic data
9. Capability to alternate between graphic and text displays
10. Use of Windowing software

2.4 ECC SOFTWARE (Existing)

- A. The following control programs shall be used for this project:
 1. A Temporary Scheduler program which will allow the operator to override preset time clock operation of equipment.
 2. A Time and Event Program which will initiate a controlled sequence of events for execution at a specific time or upon the occurrence of an event.
 3. System Services: Set of routines to supply common software services to applications and operator interface programs as follows:
 - a. A psychometric routine is to convert direct measurements of drybulb and dewpoint or relative humidity (RH) to humidity ratio and enthalpy values usable by the EMS application programs.
 - b. An alarm lockout routine to inhibit nuisance alarms.
 - c. A floating alarm limit routine which will allow analog alarm limits to automatically adjust upward or downward with application program control or manual adjustment of set points. Alarm differentials above and below setpoint are to be field adjustable.
- E. System Graphics: Using the graphic system software, edit, graphical representation of the building(s), the building mechanical systems, and the DDC system to include the **remodeled project areas**. All the demolished areas obsolete graphics shall be replaced with the new areas updated graphics. The current value and point of every I/O point shall be shown on at least one graphic and its appropriate physical location relative to building and mechanical systems. The intent of the graphic based software is to provide an ergonomic interface to the DDC system that encourages effective and efficient interaction with the system. In addition, the system shall be provided with the following:

1. Graphics shall closely follow the style of the control diagrams showing on the project drawings in representing mechanical systems, sensors, controlled devices, and point names.
2. Graphics shall have identifying title visible when the graphic is being viewed.
3. Point data shall update dynamically on the graphics when the workstation is on line with the control system.
4. For systems without graphics to give the same hierarchical affect provided by graphic penetration.
5. Mechanical System Graphics: Provide three dimensional drawings to symbolize mechanical equipment; do not use line drawings. Show controlled or sensed mechanical equipment. Each graphic shall consist of a single mechanical system; for example, graphic for an air handling unit, a graphic for a VAV box, a graphic for a heating hot water system, and a graphic for a chilled water system, etc. Place sensors and controlled devices associated with mechanical equipment in their appropriate locations. Place point name and point value adjacent to sensor or controlled device. Provide visual indication of each point in alarm. Condition, such as zone temperature, associated with mechanical system shall be shown on the graphic. Point values shall update dynamically on the graphic.
6. Trend data shall be displayed graphically, with control variable and process variable plotted as functions of time on the same chart. At the operator's discretion trend data shall be plotted real time.

F. CCRT Screen Segregation:

1. A portion of the CRT screen shall be dedicated to change of status (COS) displays. A header line is to be provided for information relative to current conditions, and shall continuously display day of week in full English, day, month, and year. Outdoor air temperature, outdoor air relative humidity, and the initials of the operator currently signed on shall be displayed in this dedicated area. The dedicated display shall indicate the type of COS, such as Smoke Alarm, Mechanical Alarm, Mechanical Alarm Acknowledge, and Trouble Condition, followed by the time of concurrence and an appropriate action taken message.

Also provide a complete English language description of the point. Description, display and printout shall include physical location, such as Mechanical Bay 4-3 100-AH61 discharge air.

2. Alarm display: Alarm conditions shall generate an audible alarm and cause a flashing alphanumeric display in the dedicated area on the screen. In addition, a graphic diagram of the mechanical system of floor plan associated with alarm shall be automatically indexed. Depressing the execute button shall display the graphic. The displayed graphic shall show all related system points, their values and status. Acknowledgment of the COS condition shall cause the audible to silence. When the alarm is acknowledged the displayed value or status will stop flashing. Multiple alarm occurrences shall be displayed and printed out. The alarms are to be buffered and displayed sequentially in order of priority.
3. The CRT shall display real-time data, allow operator commands, report system activity and shall be capable of performing all programming functions specified.

2.5 PORTABLE OPERATOR'S TERMINAL (pot)

- A. Provide a portable operator's terminal (POT) that shall be capable of accessing all system data. POT may be connected to any point on the system network or may be connected directly to any controller for programming, setup, and troubleshooting. POT shall communicate using BACnet protocol. POT may be connected to any point on the system network or it may be connected directly to controllers using the BACnet PTP (Point-To-Point) Data Link/ Physical layer protocol. The terminal shall use the Read (Initiate) and Write (Execute) BACnet Services. POT shall be an IBM-compatible notebook-style PC including all software and hardware required.
- B. Hardware: POT shall conform to the BACnet Advanced Workstation (B-AWS) Profile and shall be BTL-Listed as a B-AWS device.
 1. POT shall be commercial standard with supporting 32- or 64-bit hardware (as limited by the direct-digital control system software) and software enterprise server. Internet Explorer v6.0 SP1 or higher, Windows Script Hosting version 5.6 or higher, Windows Message Queuing, Windows Internet Information Services (IIS) v5.0 or

higher, minimum 2.8 GHz processor, minimum 500 GB 7200 rpm SATA hard drive with 16 MB cache, minimum 2GB DDR3 SDRAM (minimum 1333 Mhz) memory, 512 MB video card, minimum 16 inch (diagonal) screen, 10-100-1000 Base-TX Ethernet NIC with an RJ45 connector or a 100Base-FX Ethernet NIC with an SC/ST connector, 56,600 bps modem, an ASCII RS-232 interface, and a 16 speed high density DVD-RW+/- optical drive.

- C. Software: POT shall include software equal to the software on the ECC and should also include Microsoft Office Professional 2010 & Adobe Professional.

2.6 SYSTEM SIGNAL TRANSMISSION

- A. All CU input signal circuits shall be in metal conduit or in approved shielding cable or both. All network communications between CUs and from CUs to the ECC must be installed in metal conduit.
1. Communications between RCU controllers shall utilize a commercially available local area network which operates at 2.5 megabaud or faster. The LAN shall be capable of operating at distances of at least 1,000 meters (3300 feet) between most distant nodes. The system shall automatically reconfigure itself upon failure and restoration of line failures. Communication between RCU's and ACU's, and between RCU's and USU's shall be via RS-485 which shall operate at 9600 baud or faster.
 2. Transmission line shall be electrically isolated from the CU's and the ECC at each interface to prevent any voltages in the transmission lines from damaging any of the electronic circuits.
 3. Lightning Protection: All cables entering or exiting a building which serve as communication links (DCP to ECC or between DCPs) shall have lightning arrestor networks installed near the point where the cable penetrates the building. Both primary detection devices (such as a three electrode gas type surge arrestor or equal) and secondary protectors shall be installed as a minimum and shall be as required to reduce dangerous voltages to nondamage levels. Fuses are not permitted as communication line lightning protection devices. Suitable forms are zener diodes, optical isolation, varistors and combinations of these with the proper interconnection circuitry. Transient protection shall

protect against spikes up to 1000 volts peak voltage with a one microsecond delay time. The protective device shall be automatic, self restarting, and on duty at all times. Circuit design and protective devices shall be selected assuming a maximum of 25 ohms grounding condition.

4. All transmission bus connected devices, DCP's, shall be such that loss of any single device shall not disrupt or interfere with communication to other devices on the bus. Loss of communication with the ECC shall not cause any DCP to halt operation or to cease to perform its intended function (i.e., each DCP shall continue to operate on a stand-alone basis).

B. Intercomputer Communication:

1. Intercomputer communication shall be done using Bacnet

2.6 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 and temperature display and external adjustment:

1. Electronic Thermostats:

- a. Public Space Thermostat: Public space thermostat shall be a platinum sensor and shall not have a visible means of setpoint adjustment. Adjustment shall be via the controller to which it is connected.
- b. Patient Room thermostats: Provide a platinum space temperature sensor with setpoint adjustment and a setpoint indicator.

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

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

- d. Room sensor and humidistat covers shall be similar to match room thermostat covers in style.

2.7 FINAL CONTROL ELEMENTS AND OPERATORS

- A. Fail Safe Operation: Design and install control valves and dampers to "fail safe" in either the normally open or normally closed position as required for freeze, moisture, smoke or fire protection.
- B. Spring Ranges: Provide range as required for system sequencing and to provide tight close-off.
- C. Power Operated Control Dampers (other than VAV Boxes): Provide factory fabricated, balanced type dampers. All modulating dampers shall be opposed blade type:
 - 1. 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 / 1 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. Blades for two-position, duct mounted dampers shall be parallel, airfoil (streamlined) type for minimum noise generation and pressure drop.
 - 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. Smoke Dampers and Combination Fire/Smoke Dampers: Each damper shall be classified by Underwriter's Laboratories as a Class II/III leakage rated damper for use in smoke control systems under the latest version of UL 555S, and shall bear a UL label attesting to same. The damper manufacturer shall have tested and qualified with UL, a complete range of damper sizes covering all smoke dampers required for the project:
 - 1. UL Velocity rating are based on damper size and the number of damper actuators to properly operate the damper. Dampers must have labels and literature required by UL 555S to provide details

sufficient that the resident engineer can easily determine compliance.

2. Smoke dampers and UL approved operators shall be qualified under UL 555S to an elevated temperature of 250 degrees F. The damper and operator(s) shall meet all applicable UL 555S qualifications for both smoke dampers and operators. Operators shall be electric or pneumatic type operating at 140 kPa (20 psig) as required by the central system.
3. No smoke damper that requires manual reset or link replacement after actuation is acceptable. See drawings for required control operation.
4. Metal parts shall be aluminum, mill finish galvanized steel, zinc plated steel or stainless steel.
5. Maximum air velocity, through free area of open dampers and maximum pressure loss:
 - a. Smoke damper in air conditioning unit, 700 fpm.
 - b. Duct mounted damper, 600 meter per minute (2000 fpm). Maximum static pressure loss, 50 Pascal (0.20 inches water gage).

E. Control Valves:

1. Valves shall be rated for a minimum of 150 percent of system operating pressure at the valve location but not less than 900 kPa (125 psig).
2. Valves 50 mm (2 inches) and smaller shall be bronze body with screwed or flare connections.
3. Valves 60 mm (2-1/2 inches) and larger shall be bronze or iron body, flanged.
4. Provide 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 valve 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 through valve:
 - 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.
 - e. Two position water valves shall be line size.
7. Valves outdoors: Follow manufacturer recommendations.
- F. Damper and Valve Operators and Relays:
- 1. 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. Relays shall be of the following type:
 - a. Electrical Interlocking Relays: Electric-pneumatic (EP) or pneumatic-electric (PE) types.
 - b. Electrical pilot duty of contactor types. Provide inductive rated contracts for circuits with coils, motors or other inductive devices.

2.8 AIR FLOW CONTROL

- A. Air flow and static pressure shall be controlled via digital controller (CUs) with inputs from air flow control measuring stations and static pressure inputs as specified. Controller outputs shall be true analog output signals to pneumatic positioners. 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 air flow control programs shall be factory tested programs that are documented in the literature of the control manufacturer.
- B. Air Flow Measuring Station:
- 1. Air flow measuring stations shall measure air flow by the pilot tube traverse method. Each unit shall consist of a network or static and total pressure sensors, factory positioned and connected in parallel, to produce and equalized velocity pressure. The measured velocity pressure converted to air flow (cfm) shall have an accuracy within 2 percent of the full scale

throughout the velocity range from 200 to 1,200 meter per minute (700 to 4,000 fpm).

2. Each air flow measuring station shall be installed to meet at least the manufacturer's minimum installation conditions and shall not amplify the sound level within the duct. The maximum resistance to air flow shall not exceed 0.3 times the velocity head for the duct stations and 0.6 time the velocity head for the fan stations. The unit shall be suitable for continuous operation up to a temperature of 120 degrees C (250 degrees F).
3. Air flow measuring stations shall consist of 16 gauge sheet metal casing, an aluminum air velocity treatment and air straightening section with an open face area not less than 97 percent and a total and static pressure sensing manifold made of copper. Each station shall contain noncombustible sensors, which shall be incapable of producing toxic gases or fumes in the event of elevated duct temperatures. All interconnecting tubing shall be internal to the unit with the exception of one total pressure and one static pressure meter connection.
4. Differential pressure transducers shall measure and transmit pressure signals to the direct digital controller CU. The differential pressure transducers shall operate in one of four ranges of the total span.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Workmanship: Provide properly trained skilled technicians, regularly employed in installation of DDC systems, qualified for the work and directed by experienced engineers.
2. Work Coordination: Section 01001, GENERAL CONDITIONS.
3. Electrical Work and Safety Requirements: NFPA 70 and ANSI C2, and referenced electrical sections of these specifications.
4. All wiring cabling shall be installed in conduits. Install conduits and wiring in accordance with Specification Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS. Conduits carrying control wiring and cabling shall be dedicated to the control wiring and cabling: these conduits shall not carry power

- wiring. Provide plastic end sleeves at all conduit terminations to protect wiring from burrs.
5. Install analog signal and communication cables in conduit and in accordance with Specification Section 26 05 21. Install digital communication cables in conduit and in accordance with Specification Section 27 15 00, Communications Horizontal Cabling.
 6. 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.
 7. Install all electrical work required for a fully functional system and not shown on electrical plans or required by electrical specifications. Where low voltage (less than 50 volt) power is required, provide suitable Class B transformers.
 8. Welding and Piping: Perform in accordance with Section 15705, HVAC PIPING SYSTEMS.
 9. Except for short apparatus connections, run conduit and pneumatic tubing parallel to or at right angles to the building structure. Conceal conduit and tubing in finished spaces. Pressure test tubing for one hour at 150 percent of working pressure
 10. Install pneumatic control tubing underground in conduit of sufficient strength to prevent damage to tubing.
 11. Do not run tubing and conduit concealed under insulation or inside ducts. Mount control devices, tubing and conduit located on ducts or apparatus with external insulation on stand-off support to avoid interference with insulation.
 12. Run tubing and wire connecting devices on or in control cabinets parallel with the sides of the cabinet neatly racked to permit tracing. Rack connections bridging a cabinet door along hinge side and protect from damage. Provide grommets, sleeves, or vinyl tape to protect plastic tubing or wires from sharp edges of panels, conduit and other items.
 13. Equipment and Materials Identification: SECTION 23 05 11
COMMON WORK RESULTS FOR HVAC.

B. Field Materials:

1. Sensors and Controls:

- a. Provide all remote sensors and instrumentation.
- b. 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.
- c. Label or code each field wire at each end. 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.
- d. Temperature Sensors:
 - 1) Temperature sensors shall be readily accessible and adaptable to each type of application in such a manner as to permit for quick, each replacement and servicing without special tools or skills. Calibrate sensors to accuracy specified. In no case will sensors designed for one application be installed for another application such as replacing a duct sensor with a room sensor. Room temperature sensor should not be mounted on exterior walls when other locations are available. Mount center line of room sensor at 1.5 meters (5 feet) above finished floor.
 - 2) Mount duct sensors in locations to sense the correct temperature of the air only, within the vibration and velocity limits of the sensing element. Mount extended surface element, when used, securely within the duct and position to measure the best average temperature. Do not locate sensors in dead air spaces or positions obstructed by ducts or equipment. Thermally isolate elements from brackets and supports to respond to air temperature only. Surely seal duct penetrations.
 - 3) String duct averaging sensors between two rigid supports in a serpentine position to sense average conditions. Thermally isolate the sensing elements from supports.
 - 4) Provide outside air temperature sensors on north side of the building, away from exhaust hoods, air intakes and other areas that may effect temperature readings. Provide

sun shields to protect outside air sensors from direct sunlight.

- 5) Provide thermometers at locations indicated. Mount thermometers to allow readability when standing on the floor.

2. Damper Actuators: Actuators shall not be mounted in the air stream.

3. Pressure Sensors:

- a. Provide all pressure sensor and gauges.
- b. Install pressure sensing tips in locations to sense appropriate pressure conditions and at locations shown on the drawings.
- c. Install high pressure side of the differential switch between pump discharge and check valve.
- d. Install snubbers and isolation valves on steam pressure sensing applications.

4. Digital Controllers: Install in accordance with manufacturer's published instructions and requirements.

C. Signal Transmission System Equipment:

1. General: Install all system components in accordance with the National Electrical Code and other applicable codes as necessary in accordance with the manufacturer's recommendations.

- 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:

- 1) Keep cable runs as short as possible. Allow extra length for connecting to the terminal board.
- 2) Do not bend flexible coaxial cables in a radius less than ten times the cable outside diameter.

- 3) Use vinyl tape, sleeves, or grommets to protect cables from vibration at points where they pass around sharp corners, through walls, panel cabinets, etc.
2. Grounding: Ground system per manufacturer's requirements for proper and safe operation.

3.2 FIELD TEST AND INSPECTIONS

A. General:

1. Demonstrate function of the heating, ventilating and air-conditioning systems in compliance with the contract documents. Furnish personnel, instrumentation, and equipment necessary to perform calibration and site testing. Ensure that tests are performed by competent employees of the DDC system manufacturer regularly employed in the testing and calibration of DDC systems.
2. Testing will include the field tests and the performance verification tests. Field tests shall demonstrate proper calibration of input and output devices, and the operation of specific equipment. Performance verification tests shall ensure proper execution of the sequence of operation and proper tuning of control loops.
3. Contractor shall schedule the performance verification tests and coordinate with the Resident Engineer. Contractor shall also furnish the field test documentation to the Resident Engineer that the installed system(s) has been calibrated, tested, and ready for the performance verification test.
4. The testing shall not be done during scheduled seasonal off-periods of heating and cooling systems.

B. Field Testing and Performance Verification Tests:

1. Document all tests with detailed test results. Explain in detail the nature of each failure and corrective action taken.
2. During and after completion of the Field Tests, and again after the performance verification test, identify, determine causes, replace, repair, or calibrate equipment that fails to meet the contract specification, and deliver a written report to VA.
3. Application Software Operation Test:
 - a. Test application software for ability to communicate with the digital controllers, uploading and downloading of control programs.

- b. Demonstrate the software ability to edit the control program off line.
- c. Demonstrate reporting of alarm conditions for each alarm and ensure that workstations receives these alarms.
- d. Demonstrate ability of software to receive an save trend and status reports.

4. Performance Verification Test:

- a. Conduct the performance verification tests to demonstrate control system maintain setpoints, control loops are tuned, and controllers are programmed for the correct sequence of operation. Conduct performance verification test during --- of continuos HVAC and DDC systems operation and before final acceptance of work. The performance verification test shall demonstrate the following as a minimum:
 - 1) Furnish the VA graphed trends to show the sequence of operation is executed in correct order. And that the HVAC system operates properly through the complete sequence of operation, for example seasonal, occupied/unoccupied, warm up.
 - 2) Demonstrate hardware interlocks and safeties work, and that the control system perform the correct sequence of control after a loss of power.
 - 3) Furnish the VA graphed trends of control loops to demonstrate the control loop is stable and that setpoint is maintained. Control loop response shall respond to setpoints and stabilize in 1 minute. Control loop trend date shall be instantaneous and the time between data points shall not be greater than 1 minute.

C. Inspection and Adjustment:

- 1. Observe the HVAC system in its shut down condition. Check dampers and valves for proper normal positions. Document each position for the test report.
- 2. Check the operation of each output to verify correct operation. Command digital outputs on and off. Command analog outputs to minimum range, such as 4mA, and maximum range--10mA, measure and record commanded and actual values. Document each command and result for the test report.

3. With the digital controller, apply a control signal to each actuator and verify that the actuator operates properly from its normal position to full range of stroke position. Record actual spring ranges and normal positions for all modulating control valves and dampers. Include documentation in the test report.
 4. Demonstrate that programming is not lost after power failure, and digital controllers automatically resume proper control after a power failure.
- D. Signal Transmission System Equipment:
1. Ground Rod Tests: Before any wire is connected to the ground rods, use a portable ground testing instrument to test each ground or group of grounds.
 2. Coaxial Cable Tests: Implement NEMA WC41 as a minimum.
- E. Performance Tests: Perform in accordance with Article, QUALITY ASSURANCE.
- F. Instructions: Article, INSTRUCTIONS.
- G. Commissioning:
- A. Provide commissioning documentation in accordance with the requirements of Section 23 08 00 - COMMISSIONING OF HVAC SYSTEMS for all inspection, start up, and contractor testing required above and required by the System Readiness Checklist provided by the Commissioning Agent.
 - B. Components provided under this section of the specification will be tested as part of a larger system. Refer to Section 23 08 00 - COMMISSIONING OF HVAC SYSTEMS and related sections for contractor responsibilities for system commissioning.

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