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.

B.   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.

C.   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.

D.   The intent of this specification is to provide a peer-to peer stand-alone, distributed control system.   The minimum Baud rate shall be 78,000 Baud for FTT-10 and 1,250,000 Baud for FTT-1250.

    1.   Power wiring shall not be run in conduit with communications trunk wiring or signal or control wiring operating at 100 volts or less.

1.2   RELATED WORK

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

B.   Section 23 21 13, HYDRONIC PIPING.

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

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

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

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

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

H.   Section 26 27 26, WIRING DEVICES.

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 conditioning
      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.   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).

I.   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).

J.   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.

K.   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.

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

M.   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.

N. 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.

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

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

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

R. GIF: Abbreviation of Graphic interchange format.

S. 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.

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

U. 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.

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

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

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

Y. 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.

Z. LonTalk: An open standard protocol developed by the Echelon Corporation that uses a "Neuron Chip" for communication.

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

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

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

DD. 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.

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

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

GG. PICS: Protocol Implementation Conformance Statement.

HH. 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 Contractor shall obtain all control hardware and software supplied under this Section. The Contractor shall be responsible for the complete design, installation, and commissioning of the system. The Contractor shall be in the business of design, installation and service of such building control systems similar in size and complexity.

   2.   Equipment and Materials: Equipment and materials shall be cataloged products of manufacturers regularly engaged in production and installation of HVAC control systems. Products shall be manufacturer's latest standard design and have been tested and proven in actual use.

   3.   The Contractor shall provide a list of no less than five similar projects which have building control systems as specified in this Section. These projects must be on-line and functional such that the Department of Veterans Affairs (VA) representative would observe the control systems in full operation.

   4.   The Contractor 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.

   5.   Provide a competent and experienced Project Manager employed by the 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 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. Graphic Display: All current data shall be displayed within (10) seconds of the request.

2. Graphic Refresh: The system shall update all dynamic points with current data within (10) seconds. Data refresh shall be automatic, without operator intervention.

3. Object Command: The maximum time between the command of a binary object by the operator and the reaction by the device shall be (10) seconds. Analog objects shall start to adjust within (3) seconds.

4. 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.

5. 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.

6. 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
Electrical Power	5 percent of reading

1.6   WARRANTY

A. Labor and materials for control systems shall be warranted for a period

as specified under Warranty in FAR clause 52.246-21.

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

C.   Controls and Instrumentation subcontractor shall be responsible for temporary operations and maintenance of the control systems during the construction period until final commissioning, training of facility operators and acceptance of the project by VA.

1.7   **SUBMITTALS**

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

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

1.   A wiring diagram for each type of input device and output device including DDC controllers, modems, repeaters, etc. Diagram shall show how the device is wired and powered, showing typical connections at the digital controllers and each power supply, as well as the device itself. Show for all field connected devices, including but not limited to, control relays, motor starters, electric or electronic actuators, and temperature pressure, flow and humidity sensors and transmitters.

2.   A diagram of each terminal strip, including digital controller terminal strips, terminal strip location, termination numbers and the associated point names.

3.   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.

4.   Sequence of operations for each HVAC system and the associated control diagrams. Equipment and control labels shall correspond to those shown on the drawings.

5.   Color prints of proposed graphics with a list of points for display.

6.   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.

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.

     b.   Detailed illustrations of all the control systems specified for ease of maintenance and repair/replacement procedures, and complete calibration procedures.

     c.   Complete troubleshooting procedures and guidelines for all systems.

     d.   Complete operating instructions for all systems.

     e.   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.

     f.   Licenses, guaranty, and other pertaining documents for all equipment and systems.

     g.   Training Manuals: Submit the course outline and training material to the Owner for approval three (3) weeks prior to the training to VA facility personnel. These persons will be responsible for maintaining and the operation of the control systems, including programming. The Owner reserves the right to modify any or all of the course outline and training material.

F.   Submit Performance Report to VA 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.

   1.   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.

   2.   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 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):

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

C. American Society of Testing Materials (ASTM):

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

D. Federal Communication Commission (FCC):

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

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

    1.   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

F. National Fire Protection Association (NFPA):

    1.   70-05   National Electric Code

    2.   90A-02   Standard for Installation of Air-Conditioning and
          Ventilation Systems

G. Underwriter Laboratories Inc (UL):

    1.   94-06   Tests for Flammability of Plastic Materials for Parts and
          Devices and Appliances

    2.   294-05   Access Control System Units

    3.   486A/486B-04-   Wire Connectors

    4.   916-Rev 2-04   Energy Management Equipment

PART 2 - PRODUCTS

2.1   CONTROLS SYSTEM ARCHITECTURE

   A. General

      1.   Provide licenses for all software residing on and used by the Controls Systems and transfer these licenses to the Owner prior to completion.

   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. 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.

2.2   DIRECT DIGITAL CONTROLLERS

   A. Unitary Control Units (UCUs) shall be microprocessor-based. They shall be capable of stand-alone operation, continuing to provide stable control functions if communication is lost with the rest of the system.

      1.   Each UCU shall have sufficient memory to support its own operating system, including data sharing.

      2.   All UCUs shall be provided with LED type annunciation to continually display its operational mode, power and communications.

      3.   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.

   B. 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.

   C. Spare Equipment:

      1.   Provide spare digital controller (CU) boards and spare I/O boards as required.

      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. 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.

B. 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. Each ACU and RCU shall have capability for local readouts of all functions. The UCUs shall be read remotely.

C. 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.

D. System Security: Operator access shall be secured using individual password and operator's name. Passwords shall restrict the operator to the level of object, applications, and system functions assigned to him. A minimum of six (6) levels of security for operator access shall be provided.

E. 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.

  1. Night Setback/Morning Warm up Control: The system shall provide the ability to automatically adjust set points for this mode of operation.

2.4   SENSORS (AIR AND WATER)

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.

B.   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.

2.5   CONTROL CABLES

A.   As specified in Division 26.

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 shall have capability of being adjusted to eliminate null or dead band. Wall mounted thermostats shall have glossy white or **manufacturer's recommendation** finish, setpoint range and temperature display and external adjustment:

1.   Electronic Thermostats: Solid-state, microprocessor based, programmable to daily, weekend, and holiday schedules.

a.   Public Space Thermostat: Public space thermostat shall 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.   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.

2.7   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. Operators shall be electric as required for proper operation.

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. Duct mounted damper; 600 meter per minute (2000 fpm).
    b. Maximum static pressure loss, 50 Pascal (0.20 inches water gage).

D. 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. Two-way valves position versus flow relation shall be linear for steam and equal percentage for water flow control.

6. Maximum pressure drop:
    a. Modulating water flow control, greater of 3 meters (10 feet) of water or the pressure drop through the apparatus.
    b. Two position water valves shall be line size.

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 VA for resolution before proceeding for installation.

2.   Work Coordination: See GENERAL CONDITIONS.

3.   Install equipment, piping, wiring /conduit parallel to or at right angles to building lines.

4.   Install all equipment and piping in readily accessible locations. Do not run tubing and conduit concealed under insulation or inside ducts.

5.   Mount control devices, tubing and conduit located on ducts and apparatus with external insulation on standoff support to avoid interference with insulation.

6.   Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.

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

8.   Install equipment level and plum.

B. Electrical Wiring Installation:

1.   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.

C. Install Sensors and Controls:

   1.   Temperature Sensors:

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

       b.   Calibrate sensors to accuracy specified, if not factory calibrated.

       c.   Use of sensors shall be limited to its duty, e.g., duct sensor shall not be used in lieu of room sensor.

       d.   Install room sensors permanently supported on wall frame. They shall be mounted at 1.5 meter (5.0 feet) above the finished floor.

       e.   Mount sensors rigidly and adequately for the environment within which the sensor operates.

       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.

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.

D.   Installation of Digital Controllers and Programming:

1.   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.

2.   System point names shall be modular in design, permitting easy operator interface without the use of a written point index.

3.   Provide software programming for the applications intended for the systems specified, and adhere to the strategy algorithms provided.

4.   Provide graphics for each piece of equipment and floor plan in the building. 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:

   a.   Observe HVAC systems in shut down condition. Check dampers and valves for normal position.

   b.   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.

   c.   Demonstrate that each control loop responds to set point adjustment and stabilizes within one (1) minute. Control loop trend data shall be instantaneous and the time between data points shall not be greater than one (1) minute.

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