

**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. Engineering Control Center (ECC) shall include:
 - 1. Operator Workstation Web-Browser User Interface (UI).
 - 2. Ethernet, IP Supervisory Network.
 - 3. Graphic Operational Interface.
 - 4. Software Configuration Tools (SCT).
 - 5. Scheduling and Alarm Management software.
 - 6. Local LonWorks FTT-10 or 1250 networks.
 - 7. Network Area Controllers (NAC).
 - 8. Data and File Server (DFS).
 - 9. Unitary Control Units (UCU).
 - 10. LonMark Compliant Application Controllers and field devices.
 - 11. Connected I/O devices.
 - 12. Third party system Data Integration.
- C. The Controls Contractor's work shall include all labor, materials, special tools, equipment, enclosures, power supplies, software, software licenses, Project specific software configurations and database entries, interfaces, wiring, tubing, installation, labeling, engineering, calibration, documentation, submittals, testing, verification, training services, permits and licenses, transportation, shipping, handling, administration, supervision, management, insurance, Warranty, specified services and items required by the Contract for the complete and fully functional Controls Systems.
- D. Following control devices and systems shall be used to provide the functional requirements of HVAC equipment and systems.

1. Direct Digital Control (DDC) of HVAC equipment and systems with electric or electronic positioning of valves and dampers.
 2. Terminal units including VAV Boxes and similar units for control of room environment conditions may be equipped with integral controls furnished and installed by the equipment manufacturer or field mounted. Refer to equipment specifications and as indicated in project documents.
- E. Connect the new work to the existing ECC system or operator workstation. The existing CPU/Monitor, printer, and other peripherals may be used to form a single operator workstation. New system including interface to existing systems and equipment shall operate and function as one complete system including one database of control point objects and global control logic capabilities. Facility operators shall have complete operations and control capability over all systems, new and existing including; monitoring, trending, graphing, scheduling, alarm management, global point sharing, global strategy deployment, graphical operations interface and custom reporting as specified. Modify the existing ECC, if necessary, to accommodate the additional control points.
- F. The control subcontractor shall supply as required, all necessary hardware equipment and software packages to interface between any existing and new system Network Area Controllers (NAC) as part of this contract. Number of area controllers required is dependent on the type and quantity of devices, hardware and software points provided. Network area controllers are same as remote controller units (RCU).
- G. The control systems shall be designed such that each mechanical system shall operate under stand-alone mode. Temperature Controls contractor shall provide controllers for each mechanical system. In the event of a network communication failure, or the loss of any other controller, the control system shall continue to operate independently. Failure of the ECC shall have no effect on the field controllers, including those involved with global strategies.
- H. 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 28 31 00, FIRE DETECTION AND ALARM.
- B. Section 23 05 11, COMMON WORK RESULTS FOR HVAC AND STEAM GENERATION.
- C. Section 23 21 13, HYDRONIC PIPING
- D. Section 23 22 13, STEAM AND CONDENSATE HEATING PIPING.
- E. Section 23 36 00, AIR TERMINAL UNITS.
- F. Section 23 31 00, HVAC DUCTS AND CASINGS.
- G. Section 23 05 93, TESTING, ADJUSTING, AND BALANCING FOR HVAC.
- H. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.
- I. Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS.
- J. Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES
(600 VOLTS AND BELOW).
- K. Section 26 27 26, WIRING DEVICES.

1.3 QUALITY ASSURANCE

A. Criteria:

1. The Controls and Instrumentation System Contractor shall be Johnson Controls Minneapolis branch officer for engineering, programming, installation and service of total integrated Facility Management Systems. Distributors, manufacturer's representatives and wholesalers will not be acceptable.
2. Single Source Responsibility of subcontractor: The Contractor shall obtain hardware and software supplied under this Section and delegates the responsibility to a single source controls installation subcontractor. The controls subcontractor shall be responsible for the complete design, installation, and commissioning of the system. The controls subcontractor shall be in the business of design, installation and service of such building automation control systems similar in size and complexity.
3. Provide a competent and experienced Project Manager employed by the Controls Contractor. The Project Manager shall be supported as necessary by other Contractor employees in order to provide professional engineering, technical and management service for the work. The Project Manager shall attend scheduled Project Meetings as required and shall be empowered to make technical, scheduling and related decisions on behalf of the Controls Contractor.

B. Codes and Standards:

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

1.4 PERFORMANCE**A. The system shall conform to the following:**

1. 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.
2. Reporting Accuracy: Listed below are minimum acceptable reporting accuracies for all values reported by the specified system:

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

Note 1: for both absolute and differential pressure

1.5 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.

1.6 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, repeaters, etc. Diagram shall show how the device is wired and powered, showing typical connections at the digital controllers and each power supply, as well as the device itself. Show for all field connected devices, including but not limited to, control relays, motor starters, electric or electronic actuators, and temperature pressure, flow and humidity sensors and transmitters.
 - 2. A diagram of each terminal strip, including digital controller terminal strips, terminal strip location, termination numbers and the associated point names.
 - 3. Control dampers and control valves schedule, including the size and pressure drop.
 - 4. Installation instructions for smoke dampers and combination smoke/fire dampers.
 - 5. 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.
6. Sequence of operations for each HVAC system and the associated control diagrams. Equipment and control labels shall correspond to those shown on the drawings.
- C. Product Certificates: Compliance with Article, QUALITY ASSURANCE.
- D. As Built Control Drawings:
1. Furnish three (3) copies of as-built drawings for each control system. The documents shall be submitted for approval prior to final completion.
 2. Furnish one (1) stick set of applicable control system prints for each mechanical system for wall mounting. The documents shall be submitted for approval prior to final completion.
 3. Furnish one (1) CD-ROM in CAD DWG and/or .DXF format for the drawings noted in subparagraphs above.
- E. Operation and Maintenance (O/M) Manuals):
1. Submit in accordance with Article, INSTRUCTIONS, in Specification Section 01 00 00, GENERAL REQUIREMENTS.
 2. Include the following documentation:
 - a. General description and specifications for all components, including logging on/off, alarm handling, producing trend reports, overriding computer control, and changing set points and other variables.
 - b. Detailed illustrations of all the control systems specified for ease of maintenance and repair/replacement procedures, and complete calibration procedures.
 - c. One copy of the final version of all software provided including operating systems, programming language, operator workstation software, and graphics software.
 - d. Complete troubleshooting procedures and guidelines for all systems.
 - e. Complete operating instructions for all systems.

- f. Recommended preventive maintenance procedures for all system components including a schedule of tasks for inspection, cleaning and calibration. Provide a list of recommended spare parts needed to minimize downtime.
- g. Licenses, guaranty, and other pertaining documents for all equipment and systems.

1.7 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. First Phase: Formal instructions to the VA facilities personnel for a total of 4 hours at a time mutually agreeable to the Contractor and the VA.
 - 2. Training by independent or franchised dealers who are not direct employees of the controls supplier will not be acceptable.

1.8 PROJECT CONDITIONS (ENVIRONMENTAL CONDITIONS OF OPERATION)

- A. The ECC and peripheral devices and system support equipment shall be designed to operate in ambient condition of 20 to 35 degrees C (65 to 90 degrees F) at a relative humidity of 20 to 80 percent non-condensing.
- B. The CUs and associated equipment used in controlled environment shall be mounted in NEMA 1 enclosures for operation at 0 to 50 degrees C (32 to 122 degrees F) at a relative humidity of 10 to 90 percent non-condensing.
- C. All electronic equipment shall operate properly with power fluctuations of plus 10 percent to minus 15 percent of nominal supply voltage.
- D. Sensors and controlling devices shall be designed to operate in the environment, which they are sensing or controlling.

PART 2 - PRODUCTS

2.1 CONTROLS SYSTEM ARCHITECTURE

- A. General
 - 1. All systems shall match existing systems architecture.
- B. Network Architecture

1. The networks shall utilize only copper and optical fiber communication media as appropriate and shall comply with applicable codes, ordinances and regulations. They may also utilize digital wireless technologies if required by the VA.
2. All necessary telephone lines, ISDN lines and internet Service Provider services and connections will be provided by the owner.

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. (NAC) Network Area Controllers shall be stand-alone, multi-tasking, multi-user, real-time digital processor complete with all hardware, software, and communications interfaces, power supplies. The Controls System shall be designed and implemented entirely for use and operation on the Internet. NACs shall have access to data within the industry standard IT network to the Data Server and other NACs as needed to accomplish required global control strategies.
 1. NACs shall provide both standalone and networked direct digital control of mechanical and electrical building system controllers as required by the Specifications. The primary NAC shall support a minimum of [5,000] field points together with all associated features, sequences, schedules, applications required for a fully functional distributed processing operation.
 2. NACs shall monitor and report communication status to the Controls Systems Application. The Controls Systems shall provide a system advisory upon communication failure and restoration.
 3. All NACs on the network shall be equipped with all software functionality necessary to operate the complete user interface,

- including graphics, via a Browser connected to the Node on the network or directly via a local port on the NAC.
4. All NAC shall be provided with face mounted LED type annunciation to continually display its operational mode, power and communications.
 5. The controllers shall reside on the BACnet Ethernet (ISO 8802-3) local area network and provide Read (Initiate) and Write (Execute) services as defined in Clauses 15.5 and 15.8, respectively of ASHRAE Standard 135, to communicate BACnet objects. Objects supported shall include: Analog input, analog output, analog value, binary input, binary output, binary value, and device.
 6. Each NAC shall be provided with the necessary un-interruptible power facilities to ensure its continued normal operation during periods of line power outages of, at minimum, 1-minute duration. Normal functionality shall include all normal software processing, communication with powered field devices and network communications with other powered Controls Systems NAC, Data Servers and OWS. Each NAC shall report its communication status to the Application. The Application shall provide a system advisory upon communication failure and restoration. Each NAC shall retain program, control algorithms, and setpoint information in non-volatile memory in the event of a power failure, and shall return to normal operation upon restoration of power.
 7. Each NAC shall have sufficient memory to support its operating system, database, and program requirements, including the following:
 - a. Device and network management.
 - b. Data sharing.
 - c. Alarm and event management including custom alarm messages for each level alarm for the points noted in the I/O Schedule.
 - d. Energy management.
 - e. Historical trend data for points specified.
 - f. Maintenance report.
 - g. Scheduling.
 - h. Dial up and network communications.
 - i. Manual override monitoring.

8. Each NAC shall support firmware upgrades without the need to replace hardware and shall have a minimum of 15 percent spare capacity of secondary system controllers, point capacity and programming functions.
 9. Each NAC shall continuously perform self-diagnostics, communication diagnosis, and provide both local and remote annunciation of any detected component failures, low battery condition; and upon failure shall assume the predetermined failure mode.
 10. Each NAC shall monitor the status of all overrides and inform the operator that automatic control has inhibited, and allow the operator to manually override automatic or centrally executed command.
 11. Provide the capability to generate and modify the Controls Systems Application software-based sequences, database elements, associated operational definition information and user-required revisions to same at any designated Workstation together with the means to download same to the associated System Controllers.
 12. In the event of loss of normal power, there shall be orderly shut down of the controllers to prevent the loss of database or software programming. When power is restored flash memory, battery backup or super capacitor will be automatically loaded into non-volatile flash memory and shall be incorporated for all programming data.
- B. Auxiliary Control Units (ACUs) shall be stand-alone, multi-tasking, multi-user, real time digital processor complete with all hardware, software and communication interfaces, power supplies, and input/output modular devices.
1. ACUs shall either reside on the LonTalk FTT-10a network or provide data using LonMark standard network variable types and configuration properties.
 2. All ACUs shall be provided with LED type annunciation to continually display its operational mode, power and communications.
 3. Each ACU shall have sufficient memory to support its operating system, database including the following:
 - a. Data sharing.
 - b. Device and network management.

- c. Alarm and event management.
 - d. Scheduling.
 - e. Energy Management.
- 4. Each ACU shall support firmware upgrades without the need to replace hardware and shall have a minimum of 15 percent spare capacity of I/O functions. The type of spares shall be in the same proportion as the implemented functions on the controller, but in no case there shall be less than one point of each implemented I/O type.
 - 5. Each ACU shall continuously perform self-diagnostics, communication diagnosis, and provide both local and remote annunciation of any detected component failures, low battery condition; and upon failure shall assume the predetermined failure mode.
 - 6. 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.
- C. 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. Unitary Control Units shall either reside on the LonTalk FTT-10a network or provide data using LonMark standard network variable types and configuration properties.
 - 2. Each UCU shall have sufficient memory to support its own operating system, including data sharing.
 - 3. All UCUs shall be provided with LED type annunciation to continually display its operational mode, power and communications.
 - 4. 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.
- D. Provide I/O module that connects sensors and actuators onto the field bus network for use by the direct digital controllers. I/O devices

shall support the communication technology specified for each controller.

1. Analog input shall allow the monitoring of low voltage (0-10 VDC), current (4-20 ma), or resistance signals (thermistor, RTD). Analog input shall be compatible with, and field configurable to commonly available sensing devices. Analog output shall provide a modulating signal for these control devices.
2. Binary inputs shall allow the monitoring of on/off signals from remote devices. Binary inputs shall provide a wetting current of at least 12 milliamps to be compatible with commonly available control devices. Binary outputs shall provide on/off operation, or a pulsed low voltage signal for pulse width modulation control. Outputs shall be selectable for either normally open or normally closed operation.
3. Binary outputs on remote and auxiliary controllers shall have 3-position (on/off/auto) override switches and status lights. Analog outputs on remote and auxiliary controllers shall have status lights and a 2-position (auto/manual) switch and manually adjustable potentiometer for manual override.
4. Each output point shall be provided with a light emitting diode (LED) to indicate status of outputs.

E. Communication Ports:

1. NACs controllers in the DDC systems shall be connected in a system local area network using protocol defined by ASHRAE Standard 135, BACnet protocol.
2. The control supplier shall provide connectors, repeaters, hubs, and routers necessary for inter-network communication.
3. Minimum baud rate between the peer-to-peer controllers in the system LAN shall be maintained at the rate of 10 Mbps. Minimum baud for the low level controllers between UCUs and ACUs, ACUs and NAC's shall be maintained at the rate of 76 Kbps.
4. Provide RS-232 port with DB-9 or RJ-11 connector for communication with each controller that will allow direct connection of standard printers, operator terminals, modems, and portable laptop operator's terminal. Controllers shall allow temporary use of portable devices

without interrupting the normal operation of permanently connected modems, printers or terminals.

5. Database, such as points; status information, reports, system software, custom programs of any one controller shall be readable by any other controller on the network.

2.3 DIRECT DIGITAL CONTROLLER SOFTWARE

- A. Use existing.

2.4 SENSORS (AIR, WATER AND STEAM)

- A. Temperature and Humidity Sensors:

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

- a. Temperature Sensors: Thermistor type for terminal units and Resistance Temperature Device (RTD) with an integral transmitter type for all other sensors.

- 1) Duct sensors shall be rigid or averaging type as shown on drawings. Averaging sensor shall be a minimum of 1 linear ft of sensing element for each sq ft of cooling coil face area.

- 2) Immersion sensors shall be provided with a separable well made of stainless steel, bronze or monel material. Pressure rating of well is to be consistent with the system pressure in which it is to be installed.

- 3) Space sensors shall be equipped with set-point adjustment, override switch, display, and/or communication port as shown on the drawings. Match room thermostats, locking cover.

- 4) Wire: Twisted, shielded-pair cable.

- 5) Output Signal: 4-20 ma.

- b. Humidity Sensors: Bulk polymer sensing element type.

- 1) Duct and room sensors shall have a sensing range of 20 to 80 percent with accuracy of ± 2 to ± 5 percent RH, including hysteresis, linearity, and repeatability.

- 2) Outdoor humidity sensors shall be furnished with element guard and mounting plate and have a sensing range of 0 to 100 percent RH.

- 3) 4-20 ma continuous output signal.

c. Static Pressure Sensors: Non-directional, temperature compensated.

1) 4-20 ma output signal.

2) 0 to 5 inches wg for duct static pressure range.

3) 0 to 0.25 inch wg for Building static pressure range.

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 ENGINEERING CONTROL CENTER (ECC)—OPERATOR'S WORKSTATION

A. Use existing.

2.6 CONTROL CABLES

As specified in Division 26.

2.7 THERMOSTATS AND HUMIDISTATS

A. Room thermostats controlling heating and cooling devices shall have three modes of operation (heating - null or dead band - cooling). Thermostats for patient bedrooms shall have capability of being adjusted to eliminate null or dead band. Wall mounted thermostats shall have 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. Patient Room Thermostats: Platinum sensor with set point adjustment and an indicator.

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

d. Battery replacement without program loss.

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

- C. Freezestats shall have a minimum of 300 mm (one linear foot) of sensing element for each 0.093 square meter (one square foot) of coil area. A freezing condition at any increment of 300 mm (one foot) anywhere along the sensing element shall be sufficient to operate the thermostatic element.
- D. Room Humidistats: Provide fully proportioning humidistat with adjustable throttling range for accuracy of settings and conservation. The humidistat shall have set point scales shown in percent of relative humidity located on the instrument. Systems showing moist/dry or high/low are not acceptable.

2.8 SPECIAL CONTROLLERS

- A. Room Differential Pressure Controller: The new differential pressure in Cath Lab 3H-105 shall be maintained by controlling the quantity of air exhausted from the room. A sensor-controller shall measure and control the velocity of air flowing into or out of the room through a sampling tube installed in the wall separating the room from the adjacent space, and display the value on the room temperature LCD display control panel. The sensor controller shall meet the following as a minimum:
 - 1. Operating range: -0.200000 to +0.200000 inches of water
 - 2. Resolution: 5 percent of reading
 - 3. Accuracy: +/- 10 percent of reading +/- 0.00001 inches of water
 - 4. Analog output: 0-10 VDC or 4-20 ma

2.9 FINAL CONTROL ELEMENTS AND OPERATORS

- A. Fail Safe Operation: Control valves and dampers shall provide "fail safe" operation in either the normally open or normally closed position as required for freeze, moisture, and smoke or fire protection.
- B. Spring Ranges: Range as required for system sequencing and to provide tight shut-off.
- C. Power Operated Low Leakage Control Dampers (other than VAV Boxes): Factory fabricated, balanced type dampers. All modulating dampers shall be opposed blade type and gasketed. Blades for two-position, duct-mounted dampers shall be parallel, airfoil (streamlined) type for minimum noise generation and pressure drop.
 - 1. Leakage: Maximum leakage in closed position shall not exceed 7 L/S (15 CFMs) differential pressure for outside air and exhaust dampers

- and 200 L/S/ square meter (40 CFM/sq. ft.) at 50 mm (2 inches) differential pressure for other dampers.
2. Frame shall be galvanized steel channel with seals as required to meet leakage criteria.
 3. Blades shall be galvanized steel or aluminum, 200 mm (8 inch) maximum width, with edges sealed as required.
 4. Bearing shall be nylon, bronze sleeve or ball type.
 5. Hardware shall be zinc-plated steel. Connected rods and linkage shall be non-slip. Working parts of joints shall be brass, bronze, nylon or stainless steel.
- D. Operators shall be electric type operating at 140 kPa (20 psig) 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. Smoke damper in air handling unit; 210 meter per minute (700 fpm).
 - b. Duct mounted damper; 600 meter per minute (2000 fpm).
 - c. Maximum static pressure loss, 50 Pascal (0.20 inches water gage).
- E. Smoke Dampers and Combination Fire/Smoke Dampers: Dampers and operators are specified in Section 23 31 00, HVAC DUCTS AND CASINGS. Control of these dampers is specified under this Section.
- F. Control Valves:
1. Valves shall be rated for a minimum of 150 percent of system operating pressure at the valve location but not less than 900 kPa (125 psig).
 2. Valves 50 mm (2 inches) and smaller shall be bronze or brass body with threaded or flare connections.
 3. Valves 60 mm (2 1/2 inches) and larger shall be bronze or iron body with flanged connections.
 4. Brass or bronze seats except for valves controlling media above 100 degrees C (210 degrees F), which shall have stainless steel seats.
 5. Flow characteristics:

- a. Three way valves shall have a linear relation or equal percentage relation of flow versus 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:
 - a. Two position steam control: 20 percent of inlet gauge pressure.
 - b. Modulating Steam Control: 80 percent of inlet gauge pressure (acoustic velocity limitation).
 - c. Modulating water flow control, greater of 3 meters (10 feet) of water or the pressure drop through the apparatus.
 - d. Two position water valves shall be line size.
- G. Damper and Valve Operators and Relays:
 - 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.
 - 3. Electronic damper operators: VAV Box actuator shall be mounted on the damper axle or shall be of the air valve design, and shall provide complete modulating control of the damper. The motor shall have a closure torque of 35-inch pounds minimum with full torque applied at close off to attain minimum leakage.

2.10 AIR FLOW CONTROL

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

- a. Each air flow sensor shall contain two individual thermal sensing elements. One element shall determine the velocity of the air stream while the other element shall compensate for changes in temperature. Each thermal flow sensor and its associated control circuit and signal conditioning circuit shall be factory calibrated and be interchangeable to allow replacement of a sensor without recalibration of the entire flow station. The sensor in the array shall be located at the center of equal area segment of the duct and the number of sensors shall be adequate to accommodate the expected velocity profile and variation in flow and temperature. The airflow station shall be of the insertion type in which sensor support structures are inserted from the outside of the ducts to make up the complete electronic velocity array.
 - b. Thermal flow sensor shall be constructed of hermetically sealed thermistors or nickel chromium or reference grade platinum wire, wound over an epoxy, stainless steel or ceramic mandrel and coated with a material suitable for the conditions to be encountered. Each dual sensor shall be mounted in an extruded aluminum alloy strut.
2. Air Flow Sensor Grid Array:
- a. Each sensor grid shall consist of a lattice network of temperature sensors and linear integral controllers (ICs) situated inside an aluminum casing suitable for mounting in a duct. Each sensor shall be mounted within a strut facing downstream of the airflow and located so that it is protected on the upstream side. All wiring shall be encased (out of the air stream) to protect against mechanical damage.
 - b. The casing shall be made of welded aluminum of sufficient strength to prevent structural bending and bowing. Steel or iron composite shall not be acceptable in the casing material.
 - c. Pressure drop through the flow station shall not exceed 4 Pascal (0.015" W.G.) at 1,000 meter per minute (3,000 FPM).

3. Electronics Panel:

- a. Electronics Panel shall consist of a surface mounted enclosure complete with solid-state microprocessor and software.
- b. Electronics Panel shall be A/C powered 120 VAC or 24 VAC and shall have the capability to transmit signals of 0-5 VDC, 0-10 VDC or 4-20 ma for use in control of the HVAC Systems. The electronic panel shall have the capability to accept user defined scaling parameters for all output signals.
- c. Electronics Panel shall have the capability to digitally display airflow in CFM and temperature in degrees F. The displays shall be provided as an integral part of the electronics panel. The electronic panel shall have the capability to totalize the output flow in CFM for two or more systems, as required. A single output signal may be provided which will equal the sum of the systems totalized. Output signals shall be provided for temperature and airflow. Provide remote mounted air flow or temperature displays where indicated on the plans.
- d. Electronics Panel shall have the following:
 - 1) Minimum of 12-bit A/D conversion.
 - 2) Field adjustable digital primary output offset and gain.
 - 3) Airflow analog output scaling of 100 to 10,000 FPM.
 - 4) Temperature analog output scaling from -45 to 70 degrees C (-50 to 160 degrees F).
 - 5) Analog output resolution (full scale output) of 0.025%.
- e. All readings shall be in I.P. units.

4. Thermal flow sensors and its electronics shall be installed as per manufacturer's instructions. The probe sensor density shall be as follows:

Probe Sensor Density	
Area (sq.ft.)	Qty. Sensors
<=1	2
>1 to <4	4
4 to <8	6
8 to <12	8
12 to <16	12
>=16	16

- a. Complete installation shall not exhibit more than $\pm 2.0\%$ error in airflow measurement output for variations in the angle of flow of up to 10 percent in any direction from its calibrated orientation. Repeatability of readings shall be within $\pm 0.25\%$.
- C. Static Pressure Measuring Station:
1. Static Pressure Control:
- a. Systems shall consist of one or more static pressure sensors and transmitters along with relays or auxiliary devices as required for a complete functional system. The span of the transmitter shall not exceed two times the design static pressure at the point of measurement. The output of the transmitter shall be true representation of the input pressure with plus or minus 25 Pascal (0.1 inch) W.G. of the true input pressure.
- 1) Static pressure sensors shall have the same requirements as Airflow Measuring Devices except that total pressure sensors are optional, and only multiple static pressure sensors positioned on an equal area basis connected to a network of headers are required.
- 2) For systems with multiple major trunk supply ducts, furnish a static pressure transmitter for each trunk duct. The transmitter signal representing the lowest static pressure

shall be selected and this shall be the input signal to the CU.

- 3) The CU shall receive the static pressure transmitter signal and CU shall provide a control output signal to the supply fan capacity control device. The control mode shall be proportional plus integral (PI) (automatic reset) and where required shall also include derivative mode.
- 4) In systems with multiple static pressure transmitters, provide a switch located near the fan discharge to prevent excessive pressure during abnormal operating conditions.

D. Constant Volume Control:

1. Systems shall consist of an air flow measuring station along with such relays and auxiliary devices as required to produce a complete functional system. The transmitter shall receive its air flow signal and static pressure signal from the flow measuring station and shall have a span not exceeding three times the design flow rate. The CU shall receive the transmitter signal and shall provide an output to the fan volume control device to maintain a constant flow rate. The CU shall provide proportional plus integral (PI) (automatic reset) control mode and where required also inverse derivative mode. Overall system accuracy shall be plus or minus the equivalent of 2 Pascal (0.008 inch) velocity pressure as measured by the flow station.

E. Airflow Synchronization:

1. Systems shall consist of an air flow measuring station for each supply and return duct, the CU and such relays, as required to provide a complete functional system that will maintain a constant flow rate difference between supply and return air to an accuracy of $\pm 10\%$. In systems where there is no suitable location for a flow measuring station that will sense total supply or return flow, provide multiple flow stations with a differential pressure transmitter for each station. Signals from the multiple transmitters shall be added through the CU such that the resultant signal is a true representation of total flow.

2. The total flow signals from supply and return air shall be the input signals to the CU. This CU shall track the return air fan capacity in proportion to the supply air flow under all conditions.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General:

1. Examine project plans for control devices and equipment locations; and report any discrepancies, conflicts, or omissions to Resident Engineer for resolution before proceeding for installation.
2. Work Coordination: 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. Division 26 and 28 to install all 120 volt electrical work required for a fully functional system and not shown on electrical plans or required by electrical specifications. Where low voltage power is required, provide suitable transformers.
5. Install all system components in accordance with local Building Code and National Electric Code.
 - a. Splices: Splices in shielded and coaxial cables shall consist of terminations and the use of shielded cable couplers. Terminations shall be in accessible locations. Cables shall be harnessed with cable ties.
 - b. Equipment: Fit all equipment contained in cabinets or panels with service loops, each loop being at least 300 mm (12 inches) long. Equipment for fiber optics system shall be rack mounted, as applicable, in ventilated, self-supporting, code gauge steel enclosure. Cables shall be supported for minimum sag.
 - c. Cable Runs: Keep cable runs as short as possible. Allow extra length for connecting to the terminal board. Do not bend flexible coaxial cables in a radius less than ten times the cable outside diameter.
 - d. Use vinyl tape, sleeves, or grommets to protect cables from vibration at points where they pass around sharp corners, through walls, panel cabinets, etc.
6. Conceal cables, except in mechanical rooms and areas where other conduits and piping are exposed.
7. Permanently label or code each point of all field terminal strips to show the instrument or item served. Color-coded cable with cable diagrams may be used to accomplish cable identification.
8. Grounding: ground electrical systems per manufacturer's written requirements for proper and safe operation.
- D. Install Sensors and Controls:
 1. Temperature Sensors:
 - a. Install all sensors and instrumentation according to manufacturer's written instructions. Temperature sensor locations shall be readily accessible, permitting quick replacement and servicing of them without special skills and tools.

- b. Calibrate sensors to accuracy specified, if not factory calibrated.
 - c. Use of sensors shall be limited to its duty, e.g., duct sensor shall not be used in lieu of room sensor.
 - d. Install room sensors permanently supported on wall frame. They shall be mounted at 1.5 meter (5.0 feet) above the finished floor.
 - e. Mount sensors rigidly and adequately for the environment within which the sensor operates.
 - f. Sensors used in mixing plenum, and hot and cold decks shall be of the averaging of type. Averaging sensors shall be installed in a serpentine manner horizontally across duct. Each bend shall be supported with a capillary clip.
 - g. All pipe mounted temperature sensors shall be installed in wells.
 - h. All wires attached to sensors shall be air sealed in their conduits or in the wall to stop air transmitted from other areas affecting sensor reading.
 - i. Permanently mark terminal blocks for identification. Protect all circuits to avoid interruption of service due to short-circuiting or other conditions. Line-protect all wiring that comes from external sources to the site from lightning and static electricity.
2. 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.
- E. Installation of Network:
1. Ethernet:
- a. The network shall employ Ethernet LAN architecture, as defined by IEEE 802.3. The Network Interface shall be fully Internet

Protocol (IP) compliant allowing connection to currently installed IEEE 802.3, Compliant Ethernet Networks.

- b. The network shall directly support connectivity to a variety of cabling types. As a minimum provide the following connectivity: 10 Base 2 (ThinNet RG-58 A/U Coaxial cabling with BNC connectors), 10 Base T (Twisted-Pair RJ-45 terminated UTP cabling).
 2. Third Party Interfaces: Contractor shall integrate real-time data from building systems by other trades and databases originating from other manufacturers as specified and required to make the system work as one system.
- F. Installation of Digital Controllers and Programming:
1. Provide a separate digital control panel for each major piece of equipment, such as air handling unit, chiller, pumping unit etc. Points used for control loop reset such as outdoor air, outdoor humidity, or space temperature could be located on any of the remote control units.
 2. Provide sufficient internal memory for the specified control sequences and trend logging. There shall be a minimum of 25 percent of available memory free for future use.
 3. System point names shall be modular in design, permitting easy operator interface without the use of a written point index.
 4. Provide software programming for the applications intended for the systems specified, and adhere to the strategy algorithms provided.
 5. Provide graphics for each piece of equipment and floor plan in the building. This includes each chiller, cooling tower, air handling unit, fan, terminal unit, boiler, pumping unit etc. These graphics shall show all points dynamically as specified in the point list.

3.2 SYSTEM VALIDATION AND DEMONSTRATION

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

1. 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. Test application software for its ability to communicate with digital controllers, operator workstation, and uploading and downloading of control programs.
 - c. Demonstrate the software ability to edit the control program off-line.
 - d. Demonstrate reporting of alarm conditions for each alarm and ensure that these alarms are received at the assigned location, including operator workstations.
 - e. Demonstrate ability of software program to function for the intended applications-trend reports, change in status etc.
 - f. Demonstrate via graphed trends to show the sequence of operation is executed in correct manner, and that the HVAC systems operate properly through the complete sequence of operation, e.g., seasonal change, occupied/unoccupied mode, and warm-up condition.

- g. Demonstrate hardware interlocks and safeties functions, and that the control systems perform the correct sequence of operation after power loss and resumption of power loss.
 - h. Prepare and deliver to the VA graphed trends of all control loops to demonstrate that each control loop is stable and the set points are maintained.
 - i. 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.
5. Witnessed validation demonstration of Operator's Terminal functions shall consist of:
- a. Running each specified report.
 - b. Display and demonstrate each data entry to show site specific customizing capability. Demonstrate parameter changes.
 - c. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.
 - d. Execute digital and analog commands in graphic mode.
 - e. Demonstrate DDC loop precision and stability via trend logs of inputs and outputs (6 loops minimum).
 - f. Demonstrate EMS performance via trend logs and command trace.
 - g. Demonstrate scan, update, and alarm responsiveness.
 - h. Demonstrate spreadsheet/curve plot software, and its integration with database.
 - i. Demonstrate on-line user guide, and help function and mail facility.
 - j. Demonstrate digital system configuration graphics with interactive upline and downline load, and demonstrate specified diagnostics.
 - k. Demonstrate multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
 - l. Demonstrate class programming with point options of beep duration, beep rate, alarm archiving, and color banding.

3.3 SEQUENCE OF OPERATION

A. Air Handling Units - AHBNW-3, AH1NW-10, AH2s-16, AHPS-54

1. Unit shall be automatically or manually enabled to run as follows:
 - a. Automatic operation shall be as defined by owner of as specified in Fan Control and Outdoor Air Control Sections.
 - b. OR Manually selected by user from graphic interface.
 - c. When the unit is stopped (manually, or from safety functions), the fans shall be de-energized, the minimum and economizer outside air (OA) dampers shall close, the exhaust air (EA) damper shall close and return air (RA) dampers shall open, the CHW valve shall close completely (except as described elsewhere during freezestat activation) and the preheat valve shall be controlled as described in preheat section.
2. Safety Shutdowns:
 - a. Freeze Protection: The unit shall shut down as described above and generate an alarm upon receiving a freezestat status on leaving side of preheat coil. Manual restart required.
 - b. High and Low Static Shutdown: The unit shall shut down and generate an alarm upon receiving either a hard-wired high or low static shutdown signal. Final setting shall be adjusted in the field, based on approximately 30% safety factory beyond normal maximum operating conditions to avoid nuisance trips, but not too exceed duct construction pressure class for each system.
 - 1) High Static Shutdown located at supply and return fan discharge,
 - 2) Low Static Shutdown located at supply and return fan suction.
 - c. General Fire Alarm: The unit shall shut down and generate an alarm upon receiving a general alarm from Fire Alarm system.
 - d. Return Air Smoke Detection: The unit shall shut down and generate an alarm upon receiving a return air smoke detector status.
 - e. Supply Air Smoke Detection: The unit shall shut down and generate an alarm upon receiving a supply air smoke detector status.
 - f. Smoke or Isolation Damper End Switch: The unit shall shut down and generate an alarm upon receiving a closed status from an associated primary isolation or smoke control damper.

3. Fan Status monitoring and alarms shall be provided as follows:
 - a. Fan Failure (supply, return): Commanded on, but the status is off.
 - b. Fan in Hand (supply, return): Commanded off, but the status is on.
 - c. Fan VFD Fault (supply, return)
 - d. Fan runtime exceeded (supply, return): Status runtime exceeds a user definable limit (adj.).
4. TEMPERATURE AND HUMIDITY CONTROL
 - a. General: The controller shall monitor the following temperature/humidity sensors and use as required for control functions as described in the sections following.
 - 1) Outside Air Temperature
 - a) networked (coordinate with VA)
 - 2) Outside Air Relative Humidity (used as required for OA Enthalpy calculation)
 - a) networked (coordinate with VA)
 - 3) Return Air Temperature:
 - a) Alarms shall be provided as follows: only during the occupied period (not during the unoccupied/optimal start periods).
 - (1) High Return Air Temp: If the return air temperature is greater than 80°F (adj.) for more than 30 minutes (adj.).
 - (2) Low Return Air Temp: If the return air temperature is less than 65°F (adj.), for more than 30 minutes (adj.).
 - 4) Mixed Air Temperature: The controller shall monitor the mixed air temperature and use as required for economizer control (if present) or preheating control (if present).
 - a) The low limit mixed air temperature sensor shall be an averaging type of sufficient length and properly arranged in furthest downstream section of mixed air plenum after air blending apparatus in order to compensate for incomplete mixing and temperature variations of the mixed air stream. The length of the sensor shall be the greater of 20' minimum or 1' per 1 sq. ft. of preheat coil face area.

b) Alarms shall be provided as follows:

- (1) High Mixed Air Temp: Only when economizer is enabled
If the mixed air temperature is greater than 5°F (adj.)
above effective MAT setpoint or upper limit of 85°F (adj.).
- (2) Low Mixed Air Temp: Only when economizer is enabled,
if the mixed air temperature is less than 5°F (adj.) below
effective MAT setpoint or lower limit of 40°F (adj.).

5) Preheat Leaving Air Temp: See Preheat Temperature Control

6) Cooling Coil Leaving Air Temp: See Cooling Temperature Control

7) Discharge Air Temperature:

a) Alarms shall be provided as follows:

- (1) High Discharge Air Temp: If greater than 5°F (adj.)
above effective DAT setpoint or upper limit of 75°F (adj.).
- (2) Low Discharge Air Temp: If less than 5°F (adj.) below
effective DAT setpoint or lower limit of 50 for recirc or
45°F (adj.) for 100%.

5. PREHEAT TEMPERATURE CONTROL

a. Steam Distributing Heating Coil with Face and Bypass and control valve:

1) Recirculation applications with high percentages of minimum OA.

a) If the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40 to 0°F (adj.) the steam valve shall open from a minimum of 10% open to a maximum of 100% open. The face and bypass dampers shall be modulated to maintain the preheat control setpoint.

b) If the outside air temperature is greater than or equal to 40°F (adj.), the face and bypass will open to full face with the steam valve modulated to maintain the preheat control setpoint

b. The PHC valve and face and bypass dampers shall fully open to coil for freeze protection whenever:

- 1) Discharge air temperature drops from 45°F (adj.) to 40°F (adj.).
- 2) Or on activation of the freezestat.

c. Alarms shall be provided as follows:

- 1) Low Preheat Fault: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT heating setpoint for more than 5 minutes (adj.) continuous.
- 2) High Temp alarm: If greater than 5°F (adj.) above effective PHDAT setpoint or upper limit of 75°F (adj.), but only when MAT is less than PHDAT setpoint.

6. COOLING COIL CONTROL

- a. The controller shall monitor the unit Discharge Air Temperature sensor and use as required for cooling coil control.
- b. The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:
 - 1) DAT exceeds effective DAT setpoint (or general cooling request).
 - 2) AND outside air temperature is greater than either than the effective DATsetpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).
 - 3) AND the economizer either disabled or fully open.
 - 4) AND the supply fan status is on.
 - 5) AND the preheating is disabled.
 - 6) The CHW valve shall open to 50% on activation of the freezestat with fans off.

7. HUMIDIFICATION

- a. The controller shall measure the return air humidity and modulate the humidifier to maintain a setpoint of 30% RH (adj.), while limiting supply air RH to a maximum of 85% (adj.). The humidifier shall be enabled whenever:
 - 1) the supply fan status is on
 - 2) AND if OA dew point temperature is below 40 deg. F. (adj.- corresponding to the dew point of maintaining humidity at approximately 70 deg F and 30% RH), then open seasonal isolation valve to enable steam to steam jacketed type humidifier tubes (if present). Edit per project requirements.
 - 3) And if the mechanical cooling output is 0% / CHW valve is closed.

b. The humidifier shall be disabled whenever:

- 1) Supply air humidity rises above safety hi-limit cutout of 95% (adj.).

c. Alarms shall be provided as follows (only when humidifier is enabled/operating):

- 1) High Supply Air Humidity: If the supply air humidity is greater than 90% rh (adj.), with +/-3% adj. hysteresis.
- 2) Low Supply Air Humidity: If the supply air humidity is less than 30% rh (adj.) with +/-3% adj. hysteresis.
- 3) Low Return Air Humidity: If the return air humidity is lower than 5% below humidification setpoint or a lower limit of 20% RH for 30 minutes.

8. ECONOMIZER MIXED AIR TEMPERATURE CONTROL

a. The controller shall modulate the economizer, relief and return dampers in sequence to maintain the mixed air temperature setpoint 2°F (adj.) less than the discharge air temperature setpoint.

b. The economizer shall be enabled whenever:

- 1) Outside air temperature is less than 68°F (adj.).
- 2) AND the outside air enthalpy is less than the return air enthalpy.
- 3) AND the supply fan status is on.
- 4) When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and retripping the freezestat.

c. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint:

- 1) First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)
 - 2) Then, economizer damper shall modulate from closed to fully open. 10-55% Economizer PID output shall open economizer damper from 0-100% open.
 - 3) Then return air damper shall modulate to fully closed. 55-100% economizer PID output shall continue to reset return damper from its controlled modulated position to achieve minimum OA and plenum pressures to fully closed, 0% open.
 - 4) Relief damper shall remain under control as defined in the Relief or Return Fan system minimum OA control sequence.
- d. The Economizer damper and exhaust air dampers shall close and the return air damper shall open when:
- 1) Mixed air temperature drops from 50°F (adj.) to 45°F (adj.).
 - 2) OR the freezestat is on
 - 3) OR loss of supply fan on status.
 - 4) OR if unit is commanded off.

9. FAN CONTROL

- a. General: Each air handling unit comprises of a supply fan array which its speed is controlled by (2) 50 % variable frequency drives operating in unison. Supply fan array speed shall be modulated to maintain the duct static pressure setpoint which shall be automatically reset to meet zone airflow demands. Return fans shall be controlled via airflow tracking to maintain an airflow differential to provide indirect building pressure control. Return fan speed to be controlled by variable frequency drive. The outside air, return and relief dampers also must be integrated with the fan tracking to ensure minimum ventilation air and to maintain proper pressure relationships within the system. The damper controls are discussed in the minimum OA and Economizer control section.

b. Supply fan:

- 1) Shall be enabled to run continuously, unless shutdown on safeties.
- 2) The initial duct static pressure setpoint shall be 1.25 in H₂O (adj.).
- 3) The supply fan array VFD minimum speed setting within the VFD itself shall be optimized in the field during system balancing and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.
- 4) An airflow measuring station(2) shall continuously monitor the total supply air fan volume in CFM and send output to the BAS.

c. Return Air Fan Control (when used): The RA fan shall be enabled in unison with the supply fan array and its speed shall be controlled in sequence along with mixing dampers to maintain building supply/return cfm tracking offset to keep the building area served at the desired airflow/pressure relationship with respect to ambient and adjacent zones; and the return/relief air plenum always slightly positive with respect to mixed air (OA/RA) plenum AND to ambient.

- 1) An airflow measuring station shall continuously monitor the total system return volume in CFM and send output to the BAS.
- 2) Airflow Tracking Control: Offset shall be maintained as calculated per section following.
- 3) Refer to Minimum OA and Economizer control sequence for coordinated mixing damper and relief fan control sequence.
- 4) The return fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system balancing and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

d. Airflow Tracking Control: Total system return air shall continuously track and trend supply and return air cfm via air flow measuring stations.

e. Fan speed control and pressure monitoring alarms shall be provided as follows:

- 1) High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than maximum limit of the DP setpoint.
- 2) Low Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) less than effective reset setpoint.

f. VFD Communications BAS Interface:

- 1) Each air handling unit contains a supply fan array which is controlled by two variable frequency drives. Each VFD shall control 50% of the supply fans and be sized for 50% of the total load.
- 2) The VFD interface shall be connected directly to the main BAS network trunk to monitor, display, trend and report the following minimum points for each VFD. VFD interface shall not be networked indirectly to the main BAS through AHU controller:
 - a) Speed output
 - b) Hand/Auto selection indication
 - c) Drive Amps
 - d) kW (compare instantaneous value, the connected motor nameplate HP/kW (constant) and the ratio)
 - e) kWhrs (include calculated energy savings from baseline if motor kW at full speed kW ran continuously at full speed)
 - f) Operating hours
 - g) Warnings
 - h) Faults

10. Smoke Cycle Operation

- a. Smoke Cycle Operation for AHBW-3, AH1NW-10, AH2S-16 does not change with work associated with this project. Smoke control zone SCZ-3-60 and SCZ-3-61 originally associated with existing air handling unit AH2S-24 to now be associated with new air handling unit AHPS-54 Controls Contractor to finalize sequence and integration into ECC.
- b. When the smoke cycle is initiated either automatically as part of a smoke interlock sequence in the ECC program or manually by the ECC operator, the unit will operate as shown in the below smoke cycle

chart. Smoke dampers are controlled individually by solenoid air valves to allow them to be opened or closed separately if an operator at the DDCC determines it is necessary to deviate from the damper position specified in the smoke cycle chart. Low limit thermostat, will be inoperative. The humidifier and cooling coil valves will be closed during the smoke cycle. In smoke mode operation the cooling coil and preheat coil valve will be closed while smoke mode valve will be modulated to maintain a 55F supply fan discharge.

- c. If a zone conditioned by this air handler is in the smoke mode, positive or negative, the DDCC will eliminate the static pressure sensors in this zone from the control selection process and will control the supply fan for the lowest static pressure sensor in the remaining zones not affected by the smoke condition.
- d. Warning
 - 1) The DDCC has no safety start/stop control of fan system in bypass mode. Use bypass mode with extreme caution as duct damage or freeze conditions may occur.

EQUIPMENT	SMOKE MODE	ADJACENT ZONE
SUPPLY FAN (SF-54)	STOP	RUN (100% VOLUME)
RETURN FAN (RF-54)	RUN	(100% VOLUME) STOP
RETURN AIR DAMPER	CLOSED	CLOSED
OUTDOOR AIR DAMPER	CLOSED	OPEN
RELIEF AIR DAMPER	OPEN	CLOSED
HUMIDIFIER VALVES	CLOSED	CLOSED
COOLING COIL VALVE	CLOSED	CLOSED
F & BP DAMPERS	MODULATE TO MAINTAIN 55F @FAN	DISCHARGE
PREHEAT VALVE	CLOSED	CLOSED
SMOKE MODE VALVE	MODULATE TO MAINTAIN 55F @FAN	DISCHARGE

2. Miscellaneous Alarms & System Diagnostics

a. Final Filter Differential Pressure Monitor:

The controller shall monitor the differential pressure across the final filters (if present).

1) Alarms shall be provided as follows: Filter Change Required:

Filter differential pressure exceeds a user definable limit (adj.).

3. Control System Object List

a. Provide at a minimum the following control points and associated I/O devices and wiring for each of the four Air Handling Units

POINT NUMBER	DESCRIPTION	TYPE	FIELD INTERFACE	ALARM	PROGRAMS	GRAPHICS
001	70-SF-x FAN CONTROL	BO	START/STOP		MCO	YES
002	70-SF-x SPEED CONTROL	AO	%SPEED		MCO	YES
003	70-SF-x VFD #1 FAILURE	BI	ALARM/NORMAL	YES		YES
004	70-SF-x VFD #1 STATUS	BI	ALARM/NORMAL	YES		YES
005	70-SF-x VFD #2 FAILURE	BI	ALARM/NORMAL	YES		YES
006	70-SF-x VFD #2 STATUS	BI	ALARM/NORMAL	YES		YES
007	70-RF-x FAN CONTROL	BO	START/STOP		MCO	YES
008	70-RF-x SPEED CONTROL	AO	%SPEED		MCO	YES
009	70-RF-x VFD #1 FAILURE	BI	ALARM/NORMAL	YES		YES
010	70-RF-x VFD #1 STATUS	BI	ALARM/NORMAL	YES		YES
011	COOLING COIL DISCHARGE AIR RELATIVE HUMIDITY	AI	DUCT RH SENSOR	YES		YES
012	COOLING COIL DISCHARGE TEMPERATURE	AI	UNIT TEMP SENSOR	YES		YES

POINT NUMBER	DESCRIPTION	TYPE	FIELD INTERFACE	ALARM	PROGRAMS	GRAPHICS
013	PRE-FILTER DIFFERENTIAL PRESSURE	AI	PRESSURE SENSOR	YES		YES
014	HUMIDIFIER OUTPUT	AO	HUMIDIFIER STEAM VALVE- 25 PSIG INLET PRESSURE		MCO	YES
015	COOLING COIL	AO	VALVE ACTUATOR		MCO	YES
016	OUTSIDE AIR DAMPERS	BO	DAMPER ACTUATORS		MCO	YES
017	SMOKE DAMPERS	BO	DAMPER ACTUATORS		MCO	YES
018	PREHEAT COIL FACE AND BYPASS DAMPERS	AO	FACE AND BYPASS COIL ACTUATOR		MCO	YES
019	HUMIDIFIER VALVE OUTPUT	BO	SOFTWARE POINT		MCO	YES
020	High Supply Air Humidity	AI	DUCT HUMIDITY SENSOR	YES		YES
021	Low Supply Air Humidity	AI	DUCT HUMIDITY SENSOR	YES		YES
022	Low Return Air Humidity	AI	DUCT HUMIDITY SENSOR	YES		YES
023	Return Air Humidity	AI	DUCT HUMIDITY SENSOR	YES		YES
024	FAN ENABLE/OFF	BO	VFD CONTROL RELAY		MCO	YES
025	PREHEAT COIL CONTROL VALVE	AO	CONTROL VALVE ACTUATOR		MCO	YES
026	UNIT COIL FREEZE PROTECTION	BI	FREEZE STAT SWITCH (MANUAL RESET)	YES		YES
027	FAN VFD GENERAL ALARM	BI	VFD CONTROL RELAY	YES		YES
028	FAN STATUS	BI	VFD CONTROL RELAY	YES		YES
029	FAN SPEED SIGNAL	AO	VFD TERMINALS FOR EXT. INPUT		MCO	YES

POINT NUMBER	DESCRIPTION	TYPE	FIELD INTERFACE	ALARM	PROGRAMS	GRAPHICS
030	SA DUCT HIGH PRESS	BO			MCO	YES
031	RA DUCT LOW PRESS	BO			MCO	YES
032	OUTSIDE AIR RELATIVE HUMIDITY	AI	DUCT RH SENSOR	YES		YES
033	OUTSIDE AIR TEMPERATURE	AI	DUCT TEMPERATURE SENSOR	YES		YES
034	MIXED AIR TEMPERATURE	AI	DUCT TEMPERATURE SENSOR	YES		YES
035	RETURN AIR TEMPERATURE	AI	DUCT TEMPERATURE SENSOR	YES		YES
036	FINAL FILTER DIFFERENTIAL PRESSURE	AI	PRESSURE SENSOR	YES		YES
037	SAFETIES INTERLOCK	BI	MULTIPLE CONTACTS TO VFD	YES		YES
038	AIR FLOW MEASURING STATION (AFMS) AIR FLOW	AI	FROM AHU AIR FLOW MEASURING STATION CONTROLLER	YES		YES
039	AIR FLOW MEASURING STATION ALARM	BI	FROM AHU AIR FLOW MEASURING STATION CONTROLLER	YES		YES
040	AIR FLOW MEASURING STATION TROUBLE	BI	FROM AHU AIR FLOW MEASURING STATION CONTROLLER	YES		YES
041	FAN SECTION DIFFERENTIAL PRESSURE	AI	DIFFERENTIAL PRESSURE SENSOR	YES		YES

B. Exhaust Air Terminal Box Control EV-1, EV-2

1. General: Modulate exhaust air terminal box airflow dampers in unison to maintain positive room pressure as measured from room pressure controller.

2. Control System Object List:

- a. Provide at a minimum the following control points and associated I/O devices and wiring

POINT NUMBER	DESCRIPTION	TYPE	FIELD INTERFACE	ALARM	PROGRAMS	GRAPHICS
042	Damper Control (TYP 2)	AO	DAMPER ACTUATORS		MCO	YES
043	Damper Position (TYP 2)	AI	DAMPER ACTUATORS		MCO	YES

C. Room Pressure Control

1. General: Sensor and monitor to maintain positive room pressure to adjacent corridor by modulating exhaust air terminal box airflow dampers. Display and alarm should be displayed on the Room Display Console.

2. Control System Object List

- a. Provide at a minimum the following control points and associated I/O devices and wiring

POINT NUMBER	DESCRIPTION	TYPE	FIELD INTERFACE	ALARM	PROGRAMS	GRAPHICS
044	Room Pressure Setpoint	AI	SOFTWARE POINT		MCO	YES
045	Room Pressure	AI	PRESSURE SENSOR		MCO	YES
046	Room Pressure	BI	PRESSURE SENSOR	YES	MCO	YES

D. Room Display Console

1. General: Wall mounted LCD touchscreen to indicate the following:
- a. Room Temperature Setpoint (Room User Adjustable)
 - b. Room Temperature Actual
 - c. Room Humidity Actual
 - d. Room Status (Occupied/Unoccupied)
 - e. Room Differential Pressure to Corridor Setpoint
 - f. Room Differential Pressure to Corridor Actual
 - g. Room Air Exchanges Actual

E. Communication with new Self Contained Air Conditioning Unit DC-1

1. Point Mapping:

- a. Map available information from each computer room air conditioning (CRAC) unit control panel using common communications protocol with CRAC unit manufacturer (see Section 238123) and display on ECC using graphics produced as a part of this project. Provide all interface equipment necessary to map points to ECC. Points shall be able to be updated from CRAC unit panel automatically at a minimum time interval of 10 seconds. At a minimum, map the below control points to the graphics. Coordinate points to map and display with COTR.

2. Control System Object List:

- a. Provide at a minimum the following control points and associated I/O devices and wiring independent of the Computer Room Air Conditioner Points:

POINT NUMBER	DESCRIPTION	TYPE	FIELD INTERFACE	ALARM	PROGRAMS	GRAPHICS
047	Room TEMPERATURE Setpoint	AI	SOFTWARE POINT		MCO	YES
048	Room Temperature	AI	TEMPERATURE SENSOR		MCO	YES
049	Room Temperature	BI	TEMPERATURE SENSOR	YES	MCO	YES
050	Unit On / Off	BI	Unit Control Panel	YES		YES

----- END -----