SECTION 15910
CONTROL SYSTEMS

PART 1 - GENERAL

1.01 PROVISIONS INCLUDED

A. The general provisions of the Contract, including General and Supplementary Conditions, and Division 1 General Requirements, apply to work specified in this Section.

B. Requirements of Section 15050, “Basic Mechanical Materials and Methods” apply to work specified in this Section.

1.02 DESCRIPTION OF WORK

A. Provide direct digital control (DDC) system as shown and consisting of high speed peer to peer network of controllers and operators workstation (OWS). Provide workstation with full graphic display, uninterrupted power supply (UPS), printers, and modems, as indicated on drawings and schedules, and by requirements of this Section

B. The direct digital control system shall be a open system architecture by means of ANSI/ASHRAE standard 135-1995 BACnet protocal and LonWorks communication protocol.

C. Work included: Provide the following:
1. Technical outline
2. 120 volt (normal or emergency) branch circuits from electrical panels to DDC panels, where required.
3. 24 volt control wiring from network DDC controllers to all application specific controllers, local display devices through end control devices, complying with requirements of Division 16.
4. 24 volt power damper actuators, including control wiring to control panels.
5. Interlock wiring from duct mounted smoke detectors to auxiliary contacts on the unit starter, and control wiring to DDC system.
6. Transformers, where required, to match control voltage with actuator or sensor voltage.
7. Interconnecting control wiring between equipment and controls.
8. General (Science Wing) Exhaust Heat Recovery Unit (EF-22).
9. Rooftop Exhaust fans.
10. Compressed air piping system including pressure reducing stations (10-20 PSIG required).
11. Services and manpower necessary for commissioning of system in coordination with the HVAC Contractor, Balancing Contractor and Owner’s representative. Comply with the USM IDAT requirements.
12. Control interface with owner furnished equipment as specified herein and on contract drawings.
13. New controls for existing equipment:
14. Constant Volume Reheat Terminal Unit Control
    a. Air Conditioning Unit Control #1 (AC-6 & 7)

b. Air Conditioning Unit Control #2 (AC-5)
c. Reset Hot Water Control
d. Air Handling Unit Control System (AH-2)
e. Hood Exhaust Fans
f. General Exhaust

D. Related work specified in other sections:
1. 13850, "Fire Alarm system"
2. Division 16 – Electrical

1.03 EXISTING BUILDING CONTROLS:

A. The Biosciences Building is monitored and controlled by a Delta native BACNET system with a DCU050 existing for the science building. The intent for this project, is to extend the Delta System to provide monitoring and control of existing systems and equipment in the Science Building

B The existing Science Building control system is a Honeywell, Inc. pneumatic system installed in 1975 with various revisions. The general intent is to maintain this pneumatic system, providing P to E and E to P devices as necessary and as appropriate to interface the existing system with the Delta System extant in the Biosciences addition. Replace exiting pneumatic controllers where necessary to provide a fully complete and functional system throughout. The 'existing sequences' listed in Part 3 are those proposed/installed in 1975 and included here as information/reference.

C. Interlocks: Unless indicated otherwise, simultaneous operation of heating and cooling equipment will not be permitted.

D. Provide complete, effective and efficient control of all HVAC systems and equipment and comply with the following:

1.04 TECHNICAL OUTLINE

A. Prepare a detailed outline describing all elements of the control system. Include a schematic system layout showing relationship of these elements and a description of how they operationally interrelate. Include technical specification data sheets for all proposed systems and devices.

B. Submit a point by point statement of compliance with the Specifications, consisting of a list of all numbered paragraphs. Where the control system complies fully, place the word "comply" opposite the paragraph number. Where the control system does not comply, or accomplishes the stated function in a manner different from that described, provide a full description of the deviation.

C. Any mention of the Control System capabilities will be interpreted as being provided unless clearly stated as not included in base bid.

D. Provide a technical outline consisting of the following items:
1. Contents, executive summary.

2. System description.
    a. System hardware description.
    b. System software description.
    c. Detailed system architecture drawing, indicating location and type of all control panels.
    d. Specification conformance.
3. Technical Data.
    a. Hardware product data sheets.
    b. Software product data sheets.
4. Implementation Plan.
    a. Installation procedures and schedules.
    b. Training issues.
5. Outline.
    a. Listing of hardware and software.
    b. Scope of work.
    c. Provide a narrative description and sequence of operation as described in Part 3, Sequence of Operation. This description shall satisfactorily explain the operation sequences and shall be in addition to the sequences described in Part 3 and not merely duplicate the description in the Specification.

1.05 DEFINITIONS

A. Algorithm: A software procedure for solving a recurrent mathematical or logical problem.

B. Analog: A continuously varying signal or value (temperature, current, velocity, etc.).

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

D. Facility Management System (Controls): The entire system of hardware and software specifically designed to centrally manage building HVAC and related utilities.

E. Controls Contractor: The Controls Contractor responsible for the installation of the Facility Management System specified herein.

F. Control Process: The software required to perform a complete control loop from input signal to interlock logic, process calculation to final output signal control.

G. Control Wiring: Includes conduit, wire and wiring devices to install a complete Control System including motor control circuits, interlocks, thermostats, PE and EP switches and like devices in the Points List summary or specified herein and required to execute the sequence of operation. Include necessary power wiring to all controls devices, digital controllers including terminal units and actuators.

H. Direct Digital Control System: The portion of the controls which provides closed loop control of all HVAC equipment.

I. Distributed Control: A system whereby all control processing is decentralized and independent of a central computer. The control system is built up of stand-alone controllers. A single controller failure shall not impact more then one system.

J. Integration: The ability of control system components from different manufacturers to connect together and provide coordinated control via real-time data exchange through a common communications data exchange protocol. Integration shall extend to the operator's workstation software, which shall support user interaction with all control system components. Methods of integration include industry standard protocols such as: BACnet, LonMark/ LonTalk, OLE for Process Control (OPC) or integrator interfaces between cooperating manufacturer's systems.

K. Network: A system of distributed control units that are linked together on a communication highway. A network allows sharing of point information between all control units. Additionally, a network provides central monitoring and control of the entire system from any distributed control unit location. First tier networks shall provide "Peer-to Peer" communications. Second tier networks shall provide either "Peer-to-Peer", Master –Slave or Supervised Token Passing communications.

L. Open Protocol Bus (OPB): A pre-programmed communications integrator that allows devices from one manufacturer to communicate and interact with those of another.

M. Open System port (OSP): A user programmable communications port that provides the ability to develop custom communications processes to integrate other operating systems with FM System.

N. Operator-Machine Interface: A method by which an operator communicates with a CONTROLS System. Operator-machine interfacing allows an operator to command, monitor, and program the system.

O. Peripheral: Input/Output (I/O) equipment used to communicate with the computer and make copies of system outputs, peripherals include CRT, printer, tape deck, diskette, etc.

P. Pick Point: A pick point is a graphical display element that allows the operator to "click" the item and automatically display the associated screen or service. Any screen may have pick points to or be linked from any other screen to provide a logical user navigation system using a ladder tree hierarchy.

Q. PID Control Loop: A mathematical calculation used to evaluate a control input and determine the control output value required to maintain the input value at setpoint. The PID (Proportional, Integral, Derivative) control loop shall have operator adjustable maximum rate of change, P and D gains and loop response time delay. The loop shall be self-integrating so that no integral constant is required and the loop shall not be subject to "Integral Windup".

R. The term "provide" means "provide complete in place", that is, furnished and installed and ready for operation and use.

1.06 SUBMITTALS

A. Technical Outline: Submit the Technical Outline with the Contractor's Initial Application for Payment.

B. Submit shop drawings for each system automatically controlled, containing the following information:
   1. Each control panel required, with internal and external wiring clearly indicated. Provide detail of panel face, including Controls, instruments, and labeling. Include concise written description of sequence of operation.
   2. Complete system architecture flow diagram, including detailed designations of all system components and local area networks.
   3. Schematic flow diagram of system showing fans, pumps, coils, dampers, valves, control devices and control points.
   4. Label each control device with setting or adjustable range of control.
   5. Required electrical wiring. Clearly differentiate between portions of wiring that are factory-installed and portions to be field-installed.
   6. Details of control panel faces, including Controls, instruments, and labeling.
   7. Sequence of operation.
   8. Detailed control points list, clearly differentiating between analog, digital and tri-state (floating) input and output points.

C. Operating and Maintenance Data: Submit in accordance with Section 01770, "Closeout Procedures and Submittals."

D. Control Valve and Control Damper Schedules.

E. Point by Point Commissioning Report: Submit commissioning report in accordance with Field Quality Control Article in Part 3.

1.07 QUALITY ASSURANCE

A. All materials and equipment to be catalogued products of the acceptable manufacturers listed that produce and install automatic temperature control systems of latest standard design that complies with the Specification requirements.

B. Install system using competent workmen who are fully trained in the installation of temperature control equipment, and are direct employees of the Controls manufacturer. Installing distributors are not acceptable.

C. Single source responsibility of DDC Contractor to include complete installation and proper operation of the control system, debugging, and proper calibration of each component in the entire system.

D. DDC Contractor to have an in-place support facility within 20 miles of the site with technical staff, spare parts inventory and all necessary test and diagnostic equipment.

E. Comply with the following:

1. NEMA standards pertaining to components and devices for DDC control systems.
2. NFPA 90A "Standard for the Installation of Air Conditioning and Ventilating Systems" where applicable to Controls and control sequences.
3. Requirements of NEC pertaining to installation of DDC control systems, including, but not limited to, remote-control, signaling and power-limited circuits.
4. Provide DDC control system components and ancillary equipment which are UL-listed and labeled.
5. Federal Communications Commission (FCC) Rules, pertaining to components and devices for DDC control systems.
6. Electronic Industries Association (EIA) Std RS-232 pertaining to interfacing requirements for connecting data terminals and communication equipment.
7. IEEE Std 488, "Standard Digital Interface for Programmable Instrumentation", for interfacing instrumentation into system.
8. ANSI X3.4, "Code for Information Interchange", requirements for interfacing computer data processing with communication terminal equipment.

1.08 DELIVERY, STORAGE, AND HANDLING

A. Provide factory shipping cartons for each piece of equipment and control device. Maintain cartons while shipping, storing and handling, as required to prevent equipment damage, and to eliminate dirt and moisture from equipment. Store equipment and materials inside and protect from weather.

1.09 WARRANTY

A. Material: The Control System shall be free from defects in material and workmanship under normal use and service. If within thirty six (36) months from the date of completion any of the equipment herein described is defective in operation, workmanship or materials, it will be replaced, repaired or adjusted at the option of the CONTROLS Contractor free of charge.

B. Installation: The Control System shall be free from defects in installation workmanship for a period of one year from acceptance. The CONTROLS Contractor shall, free of charge, correct any defects in workmanship within one week of notification in writing by the Owner.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURES

A. Air Flow Measuring System:
1. Ebtron, Incorporated.
2. Kurz
3. Air Sentinel

B. Fire and Fire/SmokeDampers:
1. Air Balance, Inc.
2. Prefco Products Inc.
3. Ruskin Mfg. Co.

C. Laboratory Control System & Equipment: Phoenix Controls Corporation

D. Flow Indication Devices: Air Direction Inc.

2.02 GENERAL

A. The direct digital control system shall be open system architecture by means of ANSI/ASHRAE standard 135-1995 BACnet protocol, LonWorks communication protocol and or open integration software using one or combination of the above two protocols.

B. Systems using integrator software to preform the work of the integrating systems (Native BACnet) are responsible for contacting the exisitng system manufactures (equipment and DDC systems) to secure documentation and programming information on the existing systems. This includes providing the hardware and software gatways. Coordinate asssignment of device and network identification. Commission the network integration up to and including the use of network "sniffers" or "protocol analyzers" to verify network message packet integrity. Provide the final documentation of the integrated inter-network.

2.03 SYSTEM ARCHITECTURE

A. First Tier Network
1. The first tier network shall be based on high speed Ethernet TCP/IP using BACnet protocol. Workstation LAN controller cards shall be standard “off the shelf” products available through normal PC vendor channels.
2. The FMS shall network multiple operator workstations, network controllers, system controllers, and application-specific controllers. The first tier network shall provide communications between operator workstations and first tier DDC (Direct Digital Control) controllers.
3. The first tier network shall operate at a minimum communication speed of 100 mbps, with full peer-to-peer network communication.
4. Network Controllers shall reside on the first tier.
5. The first tier network will be compatible with other facility-wide networks. The first tier shall be connected to a facility network by way of standard networking practices.

B. Second Tier Network
1. Second tier networks shall provide either “Peer-to-Peer,” LonWorks (lon bus) or Native BACnet MS/TP communications, and shall operate at a minimum communication speed of 78,000 baud.
2. DDC System Controllers shall reside on the second tier and be certified as either native BACnet or LonWorks (plug & play technology).

C. General Network Design: Network design to include the following provisions:
1. High speed data transfer rates for alarm reporting, quick report generation from multiple controllers, and upload/download efficiency between network devices. Minimum baud rate: 100 Mega-baud.
2. Support of any combination of controllers and the Operator Workstation directly connected to the local area network.

3. Detection and accommodation of single or multiple failures of any of the operator workstation, DDC panels or the network media. The Network is to include provisions for automatically re-configuring itself to allow all operational equipment to perform their designated functions as effectively as possible in the event of single or multiple failures.
4. Message and alarm buffering to prevent information from being lost.
5. Error detection, correction, and re-transmission to guarantee data integrity.
6. Default device definition to prevent loss of alarms or data, and ensure alarms are reported as quickly as possible in the event an operator device does not respond.
7. Commonly available, multiple sourced, networking components to be used to allow DDC system to coexist with other networking applications
8. Communications must be of a deterministic nature to assure calculable performance under worst-case network loading.
9. Automatic synchronization of real-time clocks in all DDC panels.

2.04 NETWORK CONTROLLERS

A. The Network Controller shall be a fully user-programmable, supervisory controller. The Network Controller shall monitor the network of distributed application-specific controllers, provide global strategy and direction, and communicate on a peer-to-peer basis with other Network Controllers.

B. First Tier Network – The Network Controller (NC) shall reside on the first tier network. Each NC shall support a sub-network of a minimum of 100 controllers on the second tier network and 56,000 baud modem with dedicated phone line.

C. Open Systems Port – Each controller shall have the ability to connect to third-party control systems by way of an Open Systems Port, as specified or as shown on the design drawings. All programming required to implement the OSP shall reside solely within the controller and the associated device.

D. Processor – Controllers shall be microprocessor-based with a minimum word size of 16 bits and a maximum program scan rate of 1 second. They shall be multi-tasking, multi-user, and real-time digital control processors. Controller size and capability shall be sufficient to fully meet the requirements of this Specification.

E. Memory – Each controller shall have sufficient memory to support its own operating system, databases, and control programs, and to provide supervisory control for all second tier controllers.

F. Hardware Real Time Clock – The controller shall have an integrated, hardware-based, real-time clock.

G. Communications Ports – The NC shall provide at least two RS-232 serial data communication ports for operation of operator I/O devices, such as industry-standard printers, operator terminals, modems, and portable operator's terminals. Controllers shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers, or terminals.

H. Diagnostics – Controller shall continuously perform self-diagnostics, communication diagnosis, and diagnosis of all panel components. The network controller shall provide both local and remote annunciation of any detected component failures, low battery conditions, or repeated failures to establish communication.

I. Surge and Transient Protection: Provide isolation at all network terminations, as well as all field point terminations, to suppress induced voltage transients consistent with IEEE Standard 587-1980.

J. Power Failure – In the event of the loss of normal power, there shall be an orderly shutdown of all controllers to prevent the loss of database or operating system software. Nonvolatile memory shall be incorporated for all critical controller configuration data, and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.
   1. During a loss of normal power, the control sequences shall go to the normal system shutdown conditions.
   2. Upon restoration of normal power and after a minimum off-time delay, the controller shall automatically resume full operation without manual intervention through a normal soft-start sequence.
   3. Should a controller memory be lost for any reason, the operator workstation shall automatically reload the program without any intervention by the system operators. In addition, user to have the capability of reloading DDC panel via local area network, via local RS-232C port, or via telephone line dial-in.

K. Certification – All controllers shall be listed by Underwriters Laboratories (UL).

2.05 APPLICATION SPECIFIC CONTROLLERS

A. Controllers
   1. Controller shall operate as a standalone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each Controller shall be a microprocessor-based, multi-tasking, real-time digital control processor.
   2. Controllers shall support, but not be limited to, the following configurations of systems to address current requirements and to address future expansion.
      e. Generic system interlocking through hardware.
      f. Air handling units
      g. Fume Exhaust Heat Recovery/Exhaust Units:
   3. Each controller shall have sufficient memory to support its own operating system and databases, including:
      a. Control Processes
      b. Energy Management Applications
      c. Operator I/O (Portable Service Terminal)
   4. Point types – Each controller shall support the following types of point inputs and outputs:
      a. Analog inputs shall monitor the following analog signals:
         1) 4-20 mA Sensors
         2) 0-10 VDC Sensors
         3) 1000ohm RTDs

b. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input "bouncing."
c. Counter inputs shall monitor dry contact pulses with an input resolution of one HZ minimum.
d. Analog outputs shall provide the following control outputs:
1). 4.20 mA – Sink or Source
2). 0-10 VDC
e. Binary outputs shall provide SPDT output contacts rated for 2 amps at 24 VAC. Surge and noise suppression shall be provided on all pilot relays. Inductive loads (i.e. solenoids) shall be controlled by pilot relays.
f. Tri-state outputs shall be paired binary outputs for use as Power Close/Power Open control output contacts rated for 2 amps at 24 VAC. Surge and noise suppression shall be provided on all pilot relays.
g. Pneumatic outputs shall provide a 3-15 PSI pneumatic output. Gradual override capability and output pressure gauge shall be provided.

5. Controllers shall have a built-in status, and adjust panel interface to allow for the local adjustment of all set-points, temporary override of any input or output points, and status of any points in alarm.
6. Controllers shall directly support the temporary use of a portable service terminal and or laptop that can be connected to the zone temperature sensor or directly at the controller.
7. Power fail Protection – All system set points, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the controller.
8. The capability to extend the input and output capacity of the control via Point Expansion Modules shall be provided.
a. The Point Expansion Modules shall communicate to the controller over a local RS-485 expansion bus.
b. The Point Expansion Modules shall have available a range of configurations of 4, 8, 12, or 16 data points:
1) Analog Inputs – 0-10V, 4-20mA, 1000 ohm RTD
2) Analog Outputs – 0-10V, 4-20mA
3) Digital Inputs w/ digital counter
4) Digital Outputs – triacs or relay contacts
c. Expansion module data points shall be available for inclusion in all control strategies.

B. Unitary Controllers (UNT)
1. Each Unitary Controller shall operate as a standalone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each Unitary Controller shall be a microprocessor-based, multi-tasking, real-time digital control processor.
2. Point types – Each Unitary Controller shall support the following types of point inputs and outputs:
a. Analog inputs shall monitor the following analog signals:
1) 0-10 VDC Sensors
2) 1000ohm RTDs

b. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input "bouncing."
c. Counter inputs shall monitor dry contact pulses with an input resolution of one HZ minimum.
d. Analog outputs shall provide the following control outputs:
1). 0-10 VDC
e. Binary outputs shall provide SPDT output contacts rated for 2 amps at 24 VAC. Surge and noise suppression shall be provided on all pilot relays. Inductive loads (i.e. solenoids) shall be controlled by pilot relays.
f. TriState outputs shall be paired binary outputs for use as Power Close/Power Open control output contacts rated for 2 amps at 24 VAC. Surge and noise suppression shall be provided on all pilot relays.

4. Unitary Controllers shall have a library of control routines and program logic to perform the sequence of operations specified in the "Execution" portion of this Specification.
5. Unitary Controllers shall directly support the temporary use of a portable service terminal that can be connected to the UNT via zone temperature or directly at the controller.
6. Power fail Protection – All system set points, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the UNT.

2.06 INPUT DEVICES

A. General Requirements: Installation, testing, and calibration of all sensors, transmitters, and other input devices shall be provided to meet the system requirements.

B. Temperature Sensors

1. General Requirements:
a. Provide sensors and transmitters as required.
b. The temperature sensor shall be of the resistance type, and shall be either two-wire 1000 ohm nickel RTD, or two-wire 1000 ohm platinum RTD.
c. The following point types (and the accuracy of each) are required, and their associated accuracy values include errors associated with the sensor, lead wire, and A to D conversion:

Point Type	Accuracy
Hot, Chilled and Condenser Water	± 0.5°F.
Room Temp	± 0.5°F.
Duct Temperature	± 0.5°F.
All Others	± 0.75°F.

2. Room Temperature Sensors
a. Room sensors shall be constructed for either surface or wall box mounting.
b. Room sensors shall have the following options when specified:
1) Set point reset slide switch providing a +3 degree (adjustable) range.
2) Individual heating/cooling set point slide switches.
3) A momentary override request push button for activation of after-hours operation.

4) Analog thermometer.

c. Provide heavy duty guards in Mechanical Equipment Rooms and Electrical Rooms.

3. Thermo-wells
   a. When thermo-wells are required, the sensor and well shall be supplied as a complete assembly, including well head and Greenfield fitting.
   b. Thermo-wells shall be pressure rated and constructed in accordance with the system working pressure.
   c. Thermo-wells and sensors shall be mounted in a threadolet or 1/2" NFT saddle and allow easy access to the sensor for repair or replacement.
   d. Thermo-wells shall be constructed of 316 stainless steel.
4. Outside Air Sensors
   a. Outside air sensors shall be designed to withstand the environmental conditions to which they will be exposed. They shall also be provided with a solar shield.
   b. Sensors exposed to wind velocity pressures shall be shielded by a perforated plate that surrounds the sensor element.
   c. Temperature transmitters shall be of NEMA 3R construction and rated for ambient temperatures.
5. Duct Mount Sensors
   a. Duct mount sensors shall mount in an electrical box through a hole in the duct, and be positioned so as to be easily accessible for repair or replacement.
   b. Duct sensors shall be insertion type and constructed as a complete assembly, including lock nut and mounting plate.
   c. For outdoor air duct applications, a weatherproof mounting box with weatherproof cover and gasket shall be used.
6. Averaging Sensors
   a. For ductwork greater in any dimension that 48 inches and/or where air temperature stratification exists, an averaging sensor with multiple sensing points shall be used.
   b. For plenum applications, such as mixed air temperature measurements, a string of sensors mounted across the plenum shall be used to account for stratification and/or air turbulence. The averaging string shall have a minimum of 4 sensing points per 12-foot long segment.
   c. Capillary supports at the sides of the duct shall be provided to support the sensing string.

C. Differential Pressure Transmitters
1. General Air and Water Pressure Transmitter Requirements:
   a. Pressure transmitters shall be constructed to withstand 100% pressure over-range without damage, and to hold calibrated accuracy when subject to a momentary 40% over-range input.
   b. Pressure transmitters shall transmit a 0 to 5 VDC, 0 to 10 VDC, or 4 to 20 mA output signal.
   c. Differential pressure transmitters used for flow measurement shall be sized to the flow sensing device, and shall be supplied with Tee fittings and shut-off valves in the high and low sensing pick-up lines to allow the balancing Contractor and Owner permanent, easy-to-use connection.

d. A minimum of a NEMA 1 housing shall be provided for the transmitter. Transmitters shall be located in accessible local control panels wherever possible.

2. Low Differential Water Pressure Applications (0" – 20" W.C.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of flow meter differential pressure or water pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      1) .01-20" W.C. input differential pressure range.
      2) 4-20 mA output.
      3) Maintain accuracy up to 20 to 1 ratio turndown.
      4) Reference Accuracy: +0.2% of full span.
   c. Acceptable Manufacturers: Dwyer and Mamac.
3. Medium to High Differential Water Pressure Applications (Over 21" W.C.)
   a. The differential pressure transmitter shall meet the low pressure transmitter specifications with the following exceptions:
      1) Differential pressure range 10" w.c. to 300 PSI.
      2) Reference Accuracy: +1% of full span (includes non-linearity, hysteresis, and repeatability).
   b. Standalone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.
   c. Acceptable Manufacturers: Dwyer and Mamac.
4. Building Differential Air Pressure Applications (-1" to +1" w.c.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      1) -1.00 to +1.00" W.C. input differential pressure ranges. (Select range appropriate for system application)
      2) 4-20 mA output.
      3) Maintain accuracy up to 20 to 1 ratio turndown.
      4) Reference Accuracy: +0.2% of full span.
5. Low Differential Air Pressure Applications (0" to 5" W.C.)
   a. The differential pressure transmitter shall be of industrial quality and transmit a linear, 4 to 20 mA output in response to variation of differential pressure or air pressure sensing points.
   b. The differential pressure transmitter shall have non-interactive zero and span adjustments that are adjustable from the outside cover and meet the following performance specifications:
      1) (0.00-1.00" to 5.00") W.C. input differential pressure ranges. (Select range appropriate for system application.)

2) 4-20 mA output.
3) Maintain accuracy up to 20 to 1 ratio turndown.
4) Reference Accuracy: +0.2% of full span.

6. Medium Differential Air Pressure Applications (5" to 21" W.C.)
   a. The pressure transmitter shall be similar to the Low Air Pressure Transmitter, except that the performance specifications are not as severe. Differential pressure transmitters shall be provided that meet the following performance requirements:
      1) Zero & span: (c/o F.S./Deg. F): 0.04% including linearity, hysteresis and repeatability.
      2) Accuracy: 1% F.S. (best straight line) Static Pressure Effect: 0.5% F.S. (to 100 PSIG.
      3) Thermal Effects: <+.033 F.S./Deg. F. over 40°F. to 100°F. (calibrated at 70°F.).
   b. Stand alone pressure transmitters shall be mounted in a bypass valve assembly panel. The panel shall be constructed to NEMA 1 standards. The transmitter shall be installed in the panel with high and low connections piped and valved. Air bleed units, bypass valves, and compression fittings shall be provided.

D. Smoke Detectors: Duct smoke detectors where required will be furnished by Division 13 for installation under Division 15. All wiring to the Fire Alarm System from duct smoke detectors shall be provided under Division 13.

E. Status and Safety Switches
   1. General Requirements: Switches shall be provided to monitor equipment status, safety conditions, and generate alarms at the building controls system when a failure or abnormal condition occurs. Safety switches shall be provided with two sets of contacts and shall be interlock wired to shut down respective equipment.
   2. Current Sensing Switches
      a. The current sensing switch shall be self-powered with solid state circuitry and a dry contact output. It shall consist of a current transformer, a solid state current sensing circuit, adjustable trip point, solid state switch, SPDT relay, and an LED indicating the on or off status. A conductor of the load shall be passed through the window of the device. It shall accept over-current up to twice its trip point range.
      b. Current sensing switches shall be used for run status for fans, pumps, and other miscellaneous motor loads.
      c. Current sensing switches shall be calibrated to show a positive run status only when the motor is operating under load. A motor running with a broken belt or coupling shall indicate a negative run status.
   3. Air Filter Status Switches
      a. Differential pressure switches used to monitor air filter status shall be of the automatic reset type with SPDT contacts rated for 2 amps at 120VAC.
      b. A complete installation kit shall be provided, including: static pressure tops, tubing, fittings, and air filters.
      c. Provide appropriate scale range and differential adjustment for intended service.
   4. Air Flow Switches

a. Differential pressure flow switches shall be bellows actuated mercury switches or snap acting micro-switches with appropriate scale range and differential adjustment for intended service.

5. Air Pressure Safety Switches
   a. Air pressure safety switches shall be of the manual reset type with SPDT contacts rated for 2 amps at 120VAC.
   b. Pressure range shall be adjustable with appropriate scale range and differential adjustment for intended service.
6. Water Flow Switches: Water flow switches shall be equal to the Johnson Controls P74.
7. Low Temperature Limit Switches
   a. The low temperature limit switch shall be of the manual reset type with Double Pole/Single Throw snap acting contacts rated for 16 amps at 120VAC.
   b. The sensing element shall be a minimum of 15 feet in length and shall react to the coldest 18-inch section. Element shall be mounted horizontally across duct in accordance with manufacturers recommended installation procedures.
   c. For large duct areas where the sensing element does not provide full coverage of the air stream, additional switches shall be provided as required to provide full protection of the air stream.
   d. The low temperature limit switch shall be equal to Johnson Controls A70.

F. Air Flow Measuring System:
1. General: Air flow measuring system complete with air flow/temperature sensors for duct and plenum mounting, control panel and interconnecting cable. Provide sufficient number of air flow measuring stations to allow complete air flow measuring system to read all air quantities from minimum outside air up to 100% outside air, inclusive.
2. Airflow/temperature Sensor: One or more bracketed aluminum probe assemblies weighted for the sensor area occupied for a single output, utilizing thermal, temperature compensated, thermistor sensing technology.
3. Sensor: Glass encapsulated self heated instrument grade thermistor probe and epoxy encapsulated instrument grade chip thermistor temperature sensor.
   a. Sensor velocity accuracy of ±10 feet per minute under 500 feet per minute and ±2% of reading over 500 feet per minute; sensor maximum temperature accuracy of 0.360°F.; sensor repeatability of ±0.2% scale.
   b. Operating temperature range: -20°F. to 160°F.
   c. Operating humidity range: 0 to 99% RH.
   d. Pressure drop: 0.005 inches w.g. (max.) at 2000 feet per minute.

4. Control Panel: Fully programmable microprocessor based panel for processing and transmitting sensor inputs, complete with 80 character, alph-numeric display and keypad; capable of logging outdoor air flow rates over time and downloading to the DDC system.
   a. Sensor input ports: 4 (minimum).
   b. Data logging capability: 4096 measurements (minimum).
   c. Operating temperature range: 30 degrees F. to 120 degrees F.
   d. Operating humidity range: 0 to 95% RH.
   e. Enclosure : Powder coated steel.
   f. Power connection: 24 volt, powering panel and all system sensors.

5. Connecting cable: Plenum rated, with twist-lock connector to remote control panel.

G. Hydronic Flow Measuring System:
1. Impeller Flow Meters: Impeller flow meter made for insertion in hydronic piping fluid flow to measure flow directly in gallons/minute (L/s).
2. Totalization: Include register to indicate total volume in gallons (cu. m).
3. Construction: Bronze or stainless-steel body, glass reinforced nylon impeller, ultra high molecular weight polyethylene bearings.
4. Sensor mounted in pipe saddle and isolated with gate valve for removal without interrupting system operation.
5. Panel mounted flow monitor with direct-reading calibrated scale.
6. Flow Rate: 1-30 Feet per second.
7. Pressure Rating: 150 psig (1035 kPa) minimum.
8. Temperature Rating: 220 deg F.
9. Accuracy: Plus or minus 1 percent.

2.07 OUTPUT DEVICES

A. Actuators
1. General Requirements
   a. Damper actuators associated with venturi air valves and non-freeze bypass shall be pneumatic.
   b. Unless specifically specified all control valve and dampers are 24volt.
2. Pneumatic Damper Actuators
   a. Pneumatic damper actuators shall be direct shaft mount, as manufactured by Johnson Controls, Honeywell or Belimo.
   b. Modulating and two-position actuators shall be provided as required by the sequence of operations. Damper sections shall be sized based on actuator manufacturer's recommendations for face velocity, differential pressure and damper type. The actuator mounting arrangement and spring return feature shall permit normally open or normally closed positions of the dampers, as required. All actuators (except terminal units) shall be furnished with mechanical spring return unless otherwise specified in the sequences of operations. All actuators shall have external adjustable stops to limit the travel in either direction and a gear release to allow manual positioning.
3. Pneumatic Valve Actuators
   a. Pneumatic valve actuators shall be manufactured by Johnson or Honeywell. Each actuator shall have current limiting circuitry incorporated in its design to prevent damage to the actuator.
   b. Modulating and two-position actuators shall be provided as required by the sequence of operations. Actuators shall provide the minimum torque required for proper valve close-off against the system pressure for the required application. The valve actuator shall be sized based on valve manufacturer's recommendations for flow and pressure differential. All actuators shall fail in the last position unless specified with mechanical spring return in the sequence of operations. The spring return feature shall permit normally open or normally closed positions of the valves,

as required. All direct shaft mount rotational actuators shall have external adjustable stops to limit the travel in either direction.

4. Electronic actuators: Valve actuators shall be low voltage (24 VAC), fully proportioning, properly selected for the valve body and service. Damper actuators shall be low voltage (24 VAC), linear in response to a sensed load, and properly sized to stroke the damper smoothly and efficiently throughout its range.
   a. Actuator torque shall be rated in inch pounds by the guaranteed minimum torque (GmT) method. Actuators rated by maximum torque and requiring a reducing factor based on ambient temperature, voltage conditions, and electronic component aging shall not be used.
   b. Actuators provided with spring return shall be capable of either clockwise or counter clockwise spring operation by reversing actuator on the shaft. Actuators shall be capable of being mechanically and electrically paralleled to increase torque where required.
   c. Actuators containing environmentally sensitive materials such as oil filled gear train, internal energy storage battery, internal energy storage capacitor, internal chemical energy storage shall not be used.
   d. Actuators producing less than 75 inch pound GmT shall have a power consumption no greater than 2 watts DC or 6 VA AC per unit. Actuators producing more than 75 inch pound GmT shall have a power consumption no greater than 8 watts DC or 15 VA AC per unit.
   e. Actuators shall have a combined mechanical and electrical noise level not to exceed 35 dB (A) in public areas and 45 dB (A) in mechanical areas.
   f. Actuators without spring return shall have a gear release accessible without the removal of the actuator cover, allowing the manual positioning of the air control damper.
   g. Actuators shall operate in their installed environment without exceeding the rated non condensing humidity and ambient temperature limits.
   h. Actuators shall have a minimum fifteen year design life when operating within the manufacturers' recommendations.
   i. Actuators shall be certified CSA, and UL Listed.

B. Control Dampers
   1. Furnish all automatic dampers. Automatic dampers shall be sized for the application by the Controls Contractor or as specifically indicated on the Drawings.
   2. Dampers used for throttling airflow shall be of the opposed blade type arranged for normally open or normally closed operation, as required. The damper is to be sized so that, when wide open, the pressure drop is a sufficient amount of its close-off pressure drop to shift the characteristic curve to near linear.
   3. Dampers used for two-position, open/close control shall be parallel blade type arranged for normally open or closed operation, as required.
   4. Damper frames and blades shall be constructed of either galvanized steel or aluminum. Maximum blade length in any section shall be 48". Damper blades shall be 16-gauge minimum and shall not exceed six (6) inches in width. Damper frames shall be 16-gauge minimum hat channel type with corner bracing. Additional stiffening or bracing shall be provided for any section exceeding 48" in height. All damper bearings shall be made of

stainless steel or oil-impregnated bronze. Dampers shall be tight closing, low leakage type, with synthetic elastomer seals on the blade edges and flexible stainless steel side seals. Dampers of 48”x48” size shall not leak in excess of 8.5 CFM per square foot when closed against 4" w.g. static pressure when tested in accordance with AMCA Std. 500.

C. Control Pilot Relays
   1. Control pilot relays shall be of a modular plug-in design with retaining springs or clips.
   2. Mounting bases shall be snap-mount.
   3. DPDT, 3PDT, or 4PDT relays shall be provided, as appropriate for application.
   4. Contacts shall be rated for 10 amps at 120VAC.
   5. Relays shall have an integral indicator light and check button.

D. Control Valves:
   1. All automatic control valves shall be fully proportioning and provide near linear heat transfer control. The valves shall be quiet in operation and fail-safe open, closed, or in their last position. All valves shall operate in sequence with another valve when required by the sequence of operations. All control valves shall be sized by the control manufacturer, and shall be guaranteed to meet the heating and cooling loads, as specified. All control valves shall be suitable for the system flow conditions and close against the differential pressures involved. Body pressure rating and connection type (sweat, screwed, or flanged) shall conform to the pipe schedule elsewhere in this Specification.
   2. Control valves shall be modulating plug, ball, and/or butterfly, as required by the specific application. Modulating water valves shall be sized per manufacturer’s recommendations for the given application. In general, 2-way control valves serving variable flow air handling unit coils shall be sized for a pressure drop equal to the actual coil pressure drop, but no greater than 5 PSI. Valves for terminal reheat coils shall be sized for a 2 PSIG pressure drop, but no more than a 5 PSI drop.
   3. Heating valves shall fail safe open and cooling valves shall fail safe closed, unless otherwise required by the Sequence of Operation in Part 3 of this Section.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine areas and conditions under which DDC control systems are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

3.02 ACTUATOR INSTALLATION

A. General: Actuators to be sized and applied to minimize mechanical wear and twist on air control damper blades and operating shafts in accordance with actuator manufacturers recommendations.

B. Mounting: Actuators to provide uniform torque to the air control damper drive shaft(s). Control dampers having more than three horizontally connected sections and incorporating internal frame coupling(s) to have actuators mounted on each end of the combined damper sections.

Actuators mounted on separate operating shafts of an air control damper to have an actuator repeatability of no greater than plus or minus one percent over complete angle of rotation.

3.03 AIR FLOW MEASURING SYSTEM INSTALLATION

A. General: Install air flow measuring system sensors in strict accordance with manufacturer's recommendations.

B. Install air flow measuring system control panel as indicated on Drawings.

3.04 CONTROL SYSTEMS INSTALLATION

A. Install systems and materials in accordance with manufacturer's instructions, roughing-in drawings and details shown on drawings.

B. All wiring to be properly supported and run in a neat and workmanlike manner.
   1. All wiring exposed in equipment rooms to run parallel to or at right angles to building structure.
   2. All wiring within enclosures to be neatly bundled and anchored to prevent restriction to devices and terminals.

C. All electrical work performed in installation of DDC system as described in this specification to be in accordance with the National Electrical Code (NEC) and applicable state and local codes. Properly support conduit. Size conduit for a maximum of 40% fill; ½" minimum. Provide plenum rated cable for use in return air plenums.

D. Control Wiring: Install control wiring, without splices between terminal points, color-coded. Install in accordance with National Electric Code, and in full compliance with Division 16.
   1. Install plenum rated cable in all concealed areas.
   2. Install EMT or copper tubing in exposed areas.

E. Comply with requirements of NEC, and applicable portions of NECA's "Standard of Installation" pertaining to general electrical installation practices.

F. Coordinate with other electrical work, including power distribution and equipment, as necessary to interface installation with other work.

G. Equipment:
   1. In general, locate temperature sensors, humidity sensors, and thermostats for room control immediately inside of door, 48 inches above finished floor, or where shown; coordinate sensor and/or thermostat locations with Architect.
   2. Mount local control panels at convenient locations adjacent to equipment served.
      a. Mount all relays, PE switches, pressure switches, etc., internal to DDC panels.
      b. Tag each instrument corresponding to symbols used on control diagrams.
      c. Make fully compensated capillaries connected to instruments of sufficient length to allow them to be run in neat and workmanlike manner and placed so that they will not obstruct service on equipment controlled.

3.05 SEQUENCE OF CONTROL

A. Constant Volume Reheat Terminal Unit Control
   1. The existing sequence is as follows:
      "Room thermostat maintains space temperature by first modulating damper and damper motor to its min. of 25% and then reheating with modulating control valve on hot water supply as necessary."
   2. The constant volume reheat boxes are Anemostat Type LVR-MO-W.
   3. Maintain pneumatic damper motors and hot water control valves fully operational. Replace thermostats in each room with a DDC temperature sensor. Provide appropriate interface between sensor and controllers to maintain the same or similar control.
   4. Modify system graphics to represent each room temperature and control response.

B. Air Conditioning Unit Control #1 (AC-6 & 7):
   1. The existing sequence is as follows:
      "Room thermostat maintains space temperature by modulating in sequence, heating coil valve and cooling coil valve. A 120VAC relay prevents cooling coil valve operation unless fan is running. Manual timer provides clock override for 0 – 6 Hrs. on AC-7 only."
   2. Maintain pneumatic damper motors, hot water control valves and chilled water control valves fully functional. Replace thermostats in each room with DDC temperature sensors. Provide appropriate interface between sensor and controllers to maintain the same or similar control.
   3. Remove time clock and provide start-stop signal from DDC head end.

C. Air Conditioning Unit Control #2 (AC-5):
   1. The existing sequence is as follows:
      "Control similar to Unit Control #1 above. Auxiliary contact in supply fan starter runs supply fan SAR#1 whenever AC-5 is in operation."
   2. Disable signal in supply fan starter to SAR#1. Arrange signal to open damper in supply from AH-2 whenever AC-5 is in operation.
   3. Maintain pneumatic damper motor, hot water control valve and chilled water control valve fully operational. Replace room thermostat with DDC temperature sensor. Provide appropriate interface between sensor and controllers to maintain the same or similar control.
   4. Remove time clock and provide start-stop signal from DDC head end. Provide manual override in Lecture Hall Prep Room to start AC-5 if it is otherwise off.

D. Reset Hot Water Control
   1. The existing sequence is as follows:
      "System heating water is maintained on a predetermined schedule by controller C5, in Panel CP1, sensing water temperature with T8 and reset by TSTAT T1, by modulating valve V2. Switch S2 provides for manual temperature adjustment of reset schedule. Pumps HWP 1 & 2 operate continuously during occupied periods from timer TC1 and P.E. Switch P2 whenever O.A. temperature is below 65°F. During unoccupied time TSTATS TN-1 and TN-2 will cycle circulating pumps, through P3 and P4 respectively,

by actuating relay R6, P.E. Switch prevents pump operation above 65°F O.A.T. Switch S1 is provided for clock by-pass."

2. Maintain pneumatic steam control valves fully operational. Replace insertion sensors and thermostats with DDC temperature sensors. Provide appropriate interface between sensors and controllers to maintain the same or similar control.
3. Provide occupied-unoccupied signal from DDC head end. Provide manual override to operate circulating pumps if otherwise off.
4. Provide reset schedule from DDC head end.

E Air Handling Unit Control System (AH-2)

1. The existing sequence is as follows:
   "Unit is started manually or by clock TC1 and runs continuously during occupied times. When unit is started E.P. Relays R1 and R8 open all smoke dampers by applying main air to motor M1, 3, 4, 6, 7, 8, 9 and all M11's operating the transfer dampers, between the second and third floors. The temperature in the tempered O.A. chase is maintained by controller C1, adjusting preheat coil discharge with T2 and modulating the face and by-pass damper integral with coil and coil valve in sequence. If outdoor air temperature is below 35° the controller C2 overrides the control of C1 and assures the opening of V1 is 100%. When the O.A.T is above 55° Controller C3 through Relay R2 assures the closure of V1. Freeze protection provided by TSTAT T3 stops unit fan and closes all smoke dampers if preheat coil discharge falls below 40° F. Control C4, sensing Fan AH2 discharge static pressure with P1, maintains desired system positive pressure by modulating the unit vortex damper with motor M5 TSTAT T4 indicates unit discharge temp. on gauge GA2."
2. Safety Controls for AH-2:
   a. Provide and install duct smoke detector. Provide the necessary wiring from the smoke detector to the duct mounted smoke dampers and supply fans. Upon detection of smoke unit shall be de-energized and smoke dampers shall close. Alarm DDC system. Provide signal to building fire alarm system.
   b. Provide Low temperature limit thermostat across intake plenum. De-energize unit fan when temperature falls to 40°F, close outside air damper, open valve for full steam flow to coil and alarm DDC system.
      i. Provide relays to close outside air damper when unit fan is de-energized.
      ii. Provide current relays for supply fan motor. When signal is below set point, de-energize fans and alarm DDC system.
      iii. Provide differential pressure sensor across filter media.
3. Provide low temperature limit thermostat in steam condensate return. De-energize unit fan when temperature falls to 40°F, close outside air damper, open valve for full steam flow to coil and alarm DDC system.
4. Provide damper across full face of existing IFB outside air intake heating coil. Locate damper between existing intake louver and IFB coil. Arrange damper to open fully as AH-2 start sequence is initiated and to close tightly when AH-2 is off.
5. Provide start-stop signal from DDC head end.
6. When enabled, AH-2 shall start and run with fan speed controlled to maintain pressure in distribution ductwork. Provide pressure sensor in supply riser above second floor branch take-off. Provide DDC compatible speed drive.

7. Provide air flow sensor. Measure and display supply air quantity in CFM.
8. Measure and display supply air temperature.
9. Maintain pneumatic damper motors fully operational. Provide appropriate interface between sensor and controllers to maintain the same or similar control. Set 100% damper open position to provide required air delivery on a floor by floor basis. Maintain damper motors M6, 7, 8 & 9 fully operational. Disable damper motors MSD 1 through 5.

F Hood Exhaust Fans:

1. Hood exhaust fans, speed drives and sash position controllers are existing on hoods in rooms 352A, 361, 363, and 366.
2. Provide DDC signal to enable exhaust fan for each fume hood.
3. When enabled, hood exhaust fan shall run continuously with speed drive arranged to increase exhaust air from a minimum CFM with hood sash closed to a maximum CFM with sash opened to a predetermined maximum sash position.
4. Illuminate pilot light at each hood to signify respective exhaust fan is on.

G General Exhaust:

1. Provide variable frequency drive for AF-22 with by-pass and Hand-Off-Auto Switch
2. When the H-O-A switch is in the Hand position, the fan motor shall be energized and the fan shall run. When the switch is on the Off position, the fan motor shall be de-energized and the fan shall remain off. When the switch is on Auto (normal operational position), signal fan to start/stop through building DDC system.
3. Interlock EF-22 with AH-2 such that exhaust fan shall start and run when AH-2 is started. EF-22 shall remain off if AH-2 is scheduled off or signaled off on safety.
4. Indicate exhaust fan operation to the DDC system by fan motor current sensor. A variation from current draw limits on the running fan shall constitute exhaust fan failure alarm.
5. Modulate the general exhaust variable frequency drive to maintain exhaust duct static pressure set point. The system shall also measure general exhaust air flow.
6. Provide a normally closed, spring return isolation damper upstream of the inlet to EF-22. When the fan is commanded on, the isolation damper shall open. Damper position shall confirmed open via an end switch. The isolation damper actuator shall be wired in series with the fan VFD through an integral transformer to ensure that fan and damper operation is interlocked, and that both start simultaneously. When the fan is commanded off, the isolation damper shall automatically close. (Note: The fan has a non-stall characteristic and can run against a fully closed damper).
7. With the duct static pressure at its set point and the air flow measuring station indicates the discharge velocity is falling below 3,000 fpm the DDC controller shall modulate the outside air bypass damper(s) *(normally closed, spring return)* to maintain the minimum discharge velocity at its set-point. Upon an increase in flow rate above the set point the outside bypass dampers shall modulate closed to allow the flow rate and the static pressure control to maintain the system pressure and flow rate.

3.06 IDENTIFICATION

A. Mount an input/output layout sheet within each DDC controller panel. This sheet to include the name of the points connected to each controller I/O channel.

B. Identify all DDC controllers and associated devices with symbols relating directly to control diagram. Provide field identification labels for each input and output device with the following information:
   1. Point descriptor.
   2. System name.
   3. Point type and channel number.
   4. Corresponding controller number.
   5. Wiring detail reference number.

3.07 ADJUSTING AND CLEANING

A. Start-Up: Start-up, test, and adjust control systems in presence of manufacturer's authorized representative. Demonstrate compliance with requirements. Replace damaged or malfunctioning Controls and equipment.

B. Cleaning: Clean factory-finished surfaces. Repair any marred or scratched surfaces with manufacturer's touch-up paint.

C. Final Adjustment: After completion of installation, adjust thermostats, control valves, motors and similar equipment provided as work of this section. Final adjustment performed by specially trained personnel in direct employ of manufacturer of control system.

3.08 FIELD QUALITY CONTROL

A. Upon completion of installation of system hardware and software and after circuitry has been energized, verify capability and compliance of system with requirements. Where possible, correct malfunctioning units at site, then retest to demonstrate compliance; otherwise remove and replace with new units, and proceed with retesting. Upon completion of field quality review and testing, provide a complete point by point commissioning report on all systems before system verification is begun.

3.09 SYSTEM VERIFICATION

A. Upon completion of testing specified above, the Owner's Mechanical Engineer and the installing Controls Contractor will conduct a 24 hour detailed verification of the entire system, including the following, as a minimum:
   1. Demonstrate and confirm that all systems are programmed and operating correctly.
   2. Submit diskettes (including back-up diskettes) containing up to date copies of programs in each controller.
   3. Submit four (4) printed copies of final programs that include all point definitions, weekly and annual schedule settings, controller setpoints and tuning parameters, and documented general control language (GLC) programs.

B. Verification site visits to be scheduled in two eight hour periods on consecutive days. Controls Contractor to be completely familiar with entire system.

3.10 PERSONNEL TRAINING

A. Provide competent instructors to give full instruction to designated personnel in the adjustment, operation and maintenance of system installed rather than a general training course. Instructors to be thoroughly familiar with all aspects of the subject matter they are to teach. All training to be videotaped by Controls contractor and held during normal work hours.

B. Provide 40 hours of training for Owner's operating personnel estimated six trainees. Schedule training in eight hour sessions on consecutive days. Training shall include:
   1. Explanation of drawings, operations, sequences, and maintenance manuals.
   2. Walk-through of the job to locate control components.
   3. Explanation of adjustment, calibration and replacement procedures.
   4. Explanation/demonstration of software and hardware.

C. Owner may require personnel to have more comprehensive understanding of the installation and operation. Additional training must be available from Controls Contractor. If such training is required by the Owner, it will be contracted at a later date. Provide description of available local and factory customer training.

3.11 COMMISSIONING

A. Commissioning the revised Controls system is a mandatory documented performance requirement of the Controls contractor for all control systems detailed in this Specification and sequence of operations. Commissioning shall include verification of proper installation practices by the Controls Contractor and subcontractors under the Controls Contractor, point verification and calibration, system/sequence of operation verification with respect to specified operation, and network/workstation verification. Documentation shall be presented upon completion of each commissioning step and final completion to ensure proper operation of the Facility Management System. Owner is providing a separate independent commissioning contractor in addition to the commissioning requirement by the Controls Contractor.

B. Acceptance Check List; An acceptance checklist shall be completed that documents compliance with each item of this Specification.

C. Testing Procedure: Upon completion of the installation, the Controls Contractor shall start-up the system and perform all necessary testing and run diagnostic tests to ensure proper operation. The CONTROLS Contractor shall be responsible for generating all software and entering all database information necessary to perform the sequences of control herein specified.

D. Testing Documentation: Prior to acceptance testing, Controls Contractor shall create, on an individual system basis, trend logs of input and output points, or have an automatic Point History feature for documentation purposes.

END OF SECTION 15910