SECTION 15910
CONTROL SYSTEMS

PART 1 - GENERAL

1.01 PROVISIONS INCLUDED

A. The general provisions of the Contract, including General and Supplementary General 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.

C. The work of this section will be provided under separate contract with the University of Southern Maine. Integrate and incorporate with Projects: “Research Wing Phase III Fit-Out” and “Infrastructure” for a complete and fully functioning DDC system, working under scheduling and administrative control GC, and coordinating with subs, TAB Contractor, and Owner.

1.02 DESCRIPTION OF WORK

A. Provide direct digital control (DDC) system as shown as described and consisting of high speed peer to peer network of controllers and reporting to operator workstations (OWS). Provide workstation with full graphic display, as indicated on drawings and schedules, and by requirements of this section. Control system and all of its associated components shall be electronic.

B. The direct digital control system is an extension of the existing system. This existing system has an open system architecture by means of ANSI/ASHRAE standard 135-1995 BACnet protocol.

1. ORCA System by Delta Controls - Native BACNET

2. Enterprise Building Integrator by Honeywell Controls – BACNET and LonWorks.

C. Work included:
1. Provide 120 volt (normal or emergency) branch circuits from electrical panels to DDC panels, where required.
2. Provide 24 volt control wiring from network DDC controllers to all application specific controllers, venturi air valves controllers, local display devices through end control devices, complying with requirements of Division 16.
3. Provide control valves and actuators, damper actuators, sensors, flow measuring systems, bridges, BACNET gateway, and relay communication ports between packaged units.
4. Furnish VAV box controls.
5. Provide 24 volt power damper actuators, including control wiring to control panels.
6. Provide interlock wiring from duct mounted smoke detectors to auxiliary contacts on the unit starter, and control wiring to DDC system.
7. Transformers, where required, to match control voltage with actuator or sensor voltage.

8. Provide interconnecting control wiring between equipment and controls.
9. Provide Technical Outline.
10. Exhaust Heat Recovery Unit (FEU-2).
11. High Plume Dilution Fans (EF-19, EF-20, EF-21)
12. Energy Recovery Pump (P-8).
13. Air Cooled Chiller (CH-3).
14. Air Handler (AH-4).
15. Hot water boiler (B-3).
16. Finned tube radiation control.
17. Radiant Panels.
18. Variable volume box control including interlocks with finned tube radiation.
19. Propeller Fans.
20. Laboratory airflow control system including bladder type air valves with hot water reheat coils, corrosion resistant hood exhaust venturi type air valves, corrosion resistant general room exhaust bladder type air valves.
21. Compressed air piping system including pressure reducing stations (10-20 PSIG required).
22. Lighting controls including all relays and control wiring.
23. Services and manpower necessary for start-up, adjustment & testing of system in coordination with the HVAC Contractor, Balancing Contractor and Owner's representative. Comply with the USM IDAT requirements per Spec 01810.
24. Control interface with owner furnished equipment as specified herein and on contract drawings.

D. Related work specified in other Sections:
1. Refer to Division 15 for installation of instrument wells, valve bodies, and dampers in mechanical systems.
2. Refer to applicable Division 16 Sections for power supply wiring from power source to power connection on controls and/or unit control panels. Include starters, disconnects, and required electrical devices, except where specified as furnished, or factory installed, by manufacturer.
3. Interlock wiring specified as factory-installed.
4. Smoke detectors to be furnished by Division 16 and installed by Division 15.
5. Power wiring under Division 16 includes:
   a. Wiring of power feeds through all disconnects, starters, smoke detectors, and to electric motors.
6. Four spare circuit beakers rated at 20 Amps, 120 volts, single phase (normal and emergency), have been provided at each electrical panel for DDC control system. Control system contractor to provide any additional spare circuit breakers, as required.
7. 13850, "Fire Alarm system"
8. 15950, "Testing Adjusting and Balancing.
9. 15840, "Variable Volume Boxes"

1.03 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. Provide a confirmation and back-up data on open system architecture

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

E. Provide a technical outline consisting of the following items:

1. Contents, executive summary.

2. Description of branch capabilities and branch experience.

3. 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.

4. Technical Data.
    a. Hardware product data sheets.
    b. Software product data sheets.

5. Implementation Plan.
    a. Branch operations description.
    b. Resumes of key personnel.
    c. Installation procedures and schedules.
    d. Training issues.

6. 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.

7. Support capabilities.
    a. Description of services included.
    b. Branch service capabilities.
    c. Sample service contract.

F. Where a full description of a deviation is not provided, it will be assumed that the control system does not comply with the paragraph in question.

1.04 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 (FMS): The entire system of hardware and software specifically designed to centrally manage building HVAC and related utilities.

E. CONTROLS Contractor: The Facility Management System 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. Includes necessary power wiring to all CONTROL 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, for process control (OPC) or integrator interfaces between cooperating manufacture’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 set point. 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.

1.05 SUBMITTALS

A. Technical Outline: Submit with the Contractor's Initial Application for Payment, in accordance with Section 01290 Payment Procedure, the Technical Outline described in Article 1.03.

B. Submit shop drawings for each system automatically controlled, containing the following information:
1. Indicate 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. Provide a 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. Indicate all required electrical wiring. Clearly differentiate between portions of wiring that are factory-installed and portions to be field-installed.
6. Provide details of faces of control panels, including controls, instruments, and labeling.
7. Include sequence of operation.
8. Provide example of proposed system graphics and master organizational plan.

9. Provide detailed control points list, clearly differentiating between analog, digital and tri-state (floating) input and output points.
10. Provide detailed Laboratory Airflow Control System architecture flow diagram including air valves, hood face velocity controls, zone presence sensors and sequence of operation.
11. Submit samples of four different types of room sensor covers, for selection of one by Architect.
12. Provide samples of typical graphics.

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 start-up, adjustment & testing Report: Submit start-up, adjustment & testing report in accordance with Field Quality Control Article in Part 3.

F. Comply with USM IDAT per 01810.

1.06 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. CONTROLS contractor to have a minimum of 10 year's experience with the specified control system and successful field installation.

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 50 miles of the site with technical staff, spare parts inventory and all necessary test and diagnostic equipment.

E. Comply with local and state applicable codes. In addition, 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.

F. Comply with USM IDAT per 01810.

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.

1.07 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.

B. Comply with USM IDAT per 01810.

1.08 WARRANTY

A. Material:

1. 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:

1. 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.

1.09 OWNERSHIP OF PRPRIETARY MATERIALS

A. All project developed material, software and documentation shall become the property of the owner.

PART 2 – PRODUCTS

2.01 ACCEPTABLE MANUFACTURES

A. Provide one of the following or equal CONTROLS Contractors:
   1. "ORCA Native BACnet" System by Delta Controls

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

C. Smoke Dampers:
   1. Air Balance, Inc.
   2. Prefco Products Inc.
   3. Ruskin Mfg. Co.

D. Combination Fire/Smoke Dampers:
   1. Air Balance, Inc.
   2. Prefco Products Inc.
   3. Ruskin Mfg. Co.

E. Laboratory Control System & Equipment
   1. Phoenix Controls Corporation
   2. Tek-Air Inc.
   3. TSI Inc.

F. Flow Indication Devices
   1. Air Direction Inc.

2.02 GENERAL

A. The direct digital control system is an extension of the existing system. This existing system has an open system architecture by means of ANSI/ASHRAE standard 135-1995 BACnet protocol.

B. Systems using integrator software to perform the work of the integrating systems (Native BACnet) are responsible for contacting the existing system manufactures (equipment and DDC systems) to secure documentation and programming information on the existing systems. This includes providing the hardware and software gateways. Coordinate assignment 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.

C. Provide BACnet compatible controllers.

D. USM will specify a range of panel address numbers, based on the project size that will be operated on the USM-Ethernet system. USM will control access to system and the internal addresses.

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 CONTROLS 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).

2.04 NETWORK CONTROLLERS

A. Network Controller

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

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

7. 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.

8. 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.

9. 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.

10. 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.
    a. During a loss of normal power, the control sequences shall go to the normal system shutdown conditions.
    b. 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.
    c. 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.

11. 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 described in the “Execution” portion of this Specification, and to address future expansion.
   a. Chiller (CH-3).
   b. Hot Water Boiler (B-3).
   c. Pump (P-8).
   c. Zone volumetric offset of labs.
   d. Individual lab controller
   e. Generic system interlocking through hardware.
   f. Air handling units
   g. Fume Exhaust Heat Recovery/Exhaust Units (FEU-2)(EF-19, EF-20, EF-21):

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)

3. 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. 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. Controllers shall have a built-in status, and adjust panel interface to allow for the local adjustment of all setpoints, temporary override of any input or output points, and status of any points in alarm.

5. 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.

6. Powerfail Protection – All system setpoints, 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.

7. 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. Unitary Controllers shall support, but not be limited to, the following types of systems to address specific applications described in the "Execution" portion of this Specification, and to address future expansion:
    a. Fan coil units.
    b. Roof exhaust fans.

3. 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. Powerfail Protection – All system setpoints, 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.

C. VAV Terminal Unit Controller (VMA)

1. The VMA shall provide both standalone and networked direct digital control of pressure-independent, variable air volume terminal units.

2. The VMA shall be a configurable digital controller with integral differential pressure transducer and damper actuator. All components shall be connected and mounted as a single assembly that can be removed as one piece.

3. The integral damper actuator shall be a fast response stepper motor capable of stroking 90 degrees in 30 seconds for quick damper positioning to speed start-up, adjustment & testing and troubleshooting tasks.

4. The VMA shall determine airflow by dynamic pressure measurement using an integral dead-ended differential pressure transducer. The transducer shall be maintenance-free and shall not require air filters.

5. Each VMA shall have the ability to automatically calibrate the flow sensor to eliminate pressure transducer offset error due to ambient temperature / humidity effects.

6. The VMA shall utilize a proportional plus integration (PI) algorithm for the space temperature control loops.

7. Each VMA shall continuously, adaptively tune the control algorithms to improve control and controller reliability through reduced actuator duty cycle. In addition, this tuning reduces start-up, adjustment & testing costs, and eliminates the maintenance costs of manually re-tuning loops to compensate for seasonal or other load changes.

8. The VMA shall provide the ability to download and upload VMA configuration files, both locally and via the communications network. Controllers shall be able to be loaded individually or as a group using a zone schedule generated spreadsheet of controller parameters.

9. VMA control set point changes initiated over the network shall be written to VMA non-volatile memory to prevent loss of set point changes and to provide consistent operation in the event of communication failure.

10. The VMA firmware shall be flash-upgradeable remotely via the communications bus to minimize costs of feature enhancements.

11. The VMA shall provide fail-soft operation if the airflow signal becomes unreliable, by automatically reverting to a pressure-dependent control mode.

12. The VMA shall interface with balancer tools that allow automatic recalculation of box flow pickup gain (“K” factor), and the ability to directly command the airflow control loop to the box minimum and maximum airflow set points.

13. The VMA shall be capable of direct electronic connection to the Alnor DB150 Balometer balancing hood. Connection shall be through a port located on the room sensor, or directly at the controller. As an alternative, software balancing tools shall be provided that will run in a hand-held Palm Pilot type PC (such as the 3COM Palm Pilot or IBM Workpad). The balancing tools shall allow adjustment of airflow set points and parameters, and provide permanent upload of the values entered to the VMA. The Palm Pilot shall connect to the terminal unit through the room sensor port.

14. The VMA performance shall be self-documenting via on-board diagnostics. These diagnostics shall consist of control loop performance measurements executing at each control loop’s sample interval, which may be used to continuously monitor and document system performance. The VMA shall calculate exponentially weighted moving averages (EWMA) for each of the following. These metrics shall be available to the end user for efficient management of the VAV terminals.
    1) Absolute temperature loop error.
    2) Signed temperature loop error.
    3) Absolute airflow loop error.
    4) Signed airflow loop error.
    5) Average damper actuator duty cycle.

15. The VMA shall detect system error conditions to assist in managing the VAV zones. The error conditions shall consist of:
    1) Unreliable space temperature sensor.
    2) Unreliable differential pressure sensor.
    3) Starved box.
    4) Insufficient cooling.
    5) Insufficient heating.

16. The VMA shall provide a compliant interface for ASHRAE Standard 62-1989 (indoor air quality), and shall be capable of resetting the box minimum airflow based on the percent of outdoor air in the primary air stream.

17. The VMA shall comply with ASHRAE Standard 90.1 (energy efficiency) by preventing simultaneous heating and cooling, and where the control strategy requires reset of airflow while in reheat, by modulating the box reheat device fully open prior to increasing the airflow in the heating sequence.

18. The VMA shall be compatible with the U.S. EPA Energy Star Buildings recommendations for fan energy reduction via demand-based static pressure reset down to 2/3 of duct static pressure set point, “VSD 2/3 Reset.”

19. Inputs:
    a. Analog inputs shall monitor the following analog signals, without the addition of equipment outside the terminal controller cabinet:
        1) 0-10 VDC Sensors

2) 1000ohm RTDs
3) NTC Thermistors

b. Binary inputs shall monitor dry contact closures. Input shall provide filtering to eliminate false signals resulting from input "bouncing."

c. For noise immunity, the inputs shall be internally isolated from power, communications, and output circuits.

20. Outputs

a. Analog outputs shall provide the following control outputs:
1) 0-10 VDC

b. Binary outputs shall provide a SPST Triac output rated for 500mA at 24 VAC.

c. For noise immunity, the outputs shall be internally isolated from power, communications, and other output circuits.

D. VAV Terminal Unit Controllers (VAV)

1. Each VAV Controller shall operate as a standalone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each VAV Controller shall be a microprocessor-based, multi-tasking, real-time digital control processor.

2. VAV Terminal Unit Controllers shall support, but not be limited to, the control of the following configurations of VAV boxes to address current requirements described in the "Execution" portion of this Specification, and to address future expansion:
1) Single Duct Only (Cooling with Reheat)

3. Point types – Each VAV 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. VAV 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. VAV Controllers shall directly support the temporary use of a portable service terminal that can be connected to the VAV via zone temperature or directly at the controller.

6. Powerfail 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 VAV.

2.06 INPUT DEVICES

A. General Requirements

1. 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. Sensors and transmitters shall be provided, as outlined in the input/output summary and sequence of operations.
   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**
ER, Hot and Chilled Water	± .5°F.
Room Temp	± .5°F.
Duct Temperature	± .5°F.
All Others	± .75°F.

2. Room Temperature Sensors
   a. Room sensors shall be constructed for either surface or wallbox 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.
   d. Provide explosion proof temperature sensors with heavy-duty guards in the wastewater treatment and flammable storage room. Sensors and control components to be rated for Class 1, Division 1 Group D, complying with National Electrical Code and Division 16.

3. Thermowells
   a. When thermowells are required, the sensor and well shall be supplied as a complete assembly, including well head and Greenfield fitting.
   b. Thermowells shall be pressure rated and constructed in accordance with the system working pressure.

c. Thermowells and sensors shall be mounted in a threadolet or ½” NFT saddle and allow easy access to the sensor for repair or replacement.
d. Thermowells 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): .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. 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.

D. Smoke Detectors

1. Duct smoke detectors shall be furnished as specified elsewhere in Division 16 for installation under Division 15. All wiring to the Fire Alarm System from duct smoke detectors shall be provided under Division 16. All local interlock wiring between energy recovery unit and associated exhaust fan shut-down in the event of smoke detection will be furnished and installed by controls Contractor.

E. Status and Safety Switches

1. General Requirements

a. Switches shall be provided to monitor equipment status, safety conditions, and generate alarms at the controls 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
   a. 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 0.36 degrees F.; sensor repeatability of ±0.2% scale.
   b. Operating temperature range: -20 degrees F. to 160 degrees 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, alpha-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. Humidity Sensors

1. Sensors shall be capacitance or bulk polymer resistance type.

2. Duct sensors shall be provided with a sampling chamber, and have a sensing range of 20 to 80% with an accuracy of +/- 1% R.H.

3. Space sensors shall be provided with a blank face plate and telephone jack, and have a sensing range of 20-80% R.H.

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. Humidity transmitters shall be of NEMA 3R construction.

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.

2.07 OUTPUT DEVICES

A. Actuators

1. General Requirements
   a. Damper actuators associated with bladder air valves and non-freeze bypass shall be pneumatic.
   b. Unless specifically specified all control valve and dampers are 24volt.

2. 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 guaranteed minimum torque (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 guaranteed minimum torque (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 manufacturer's recommendations.
   i. Actuators shall be certified CSA, and UL Listed.

B. Control Dampers

1. The CONTROLS Contractor shall furnish all automatic dampers. All automatic dampers shall be sized for the application by the CONTROLS Contractor or as specifically indicated on the Drawings.

2. All 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. All 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. Smoke Dampers:

1. UL-labeled according to UL 555S. Combination fire and smoke dampers shall also be UL-labeled according to UL 555.

2. Fusible Link: Replaceable, 165 degree F. rated.

3. Frame and Blades: 16-gage galvanized steel.

4. Mounting Sleeve: Factory-installed, 18-gage galvanized steel, length to suit wall or floor application.

5. Damper Motors: Provide modulating or two-position action.
   a. Permanent Split Capacitor or Shaded Pole Motors: With oil-immersed and sealed gear trains.
   b. Spring Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in-lbf and breakaway torque rating of 150 in-lbf.
   c. Outdoor Motors and Motors in Outside Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 degrees F.
   d. Nonspring Return Motors: For dampers larter the 25 square feet, size motor for running torque rating of 150 in-lbf and breakaway torque rating of 300 in-lbf.

D. Control Relays

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

E. 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. Steam control valves shall be sized for 5 PSI pressure differential. Preheating coils and Heat Exchanger for heating water system shall be sized for 1/3-2/3 duty.

4. Modulating plug water valves of the single-seat type with equal percentage flow characteristics shall be used for all hot water applications, except those described hereinafter. The valve discs shall be composition type. Valve stems shall be stainless steel.

5. Ball valves shall be used for water terminal reheat coils, fin-tube radiation, unit heaters and cabinet unit heaters.

6. 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.

2.08 LABORATORY AIRFLOW CONTROL SYSTEMS

A. A laboratory airflow control system shall be furnished and installed to control the airflow into and out of laboratory rooms. The exhaust flow rate of a laboratory fume hood shall be constant volume and precisely controlled by a venturi exhaust valve. The laboratory control system shall vary the amount of make-up/supply air into the room to operate the laboratories at the lowest possible airflow rates necessary to maintain temperature control, achieve minimum ventilation rates (6 air changes per hour), and maintain laboratory pressurization (by means of volumetric offset) in relation to adjacent spaces (positive or negative).

B. The plans and specifications for the laboratory airflow control system are based on systems and equipment manufactured by Phoenix Controls Corporation, Tek-Air or TSI, and should be BACNET compatible.

C. Equipment

1. The laboratory airflow control system supplier/manufacture shall provide a detailed proposal describing all elements of the laboratory control system. A schematic laboratory layout shall be provided, showing relations of these elements and a description of how they interact.

2. Technical specification data sheets shall be provided for all proposed system components and devices.

3. All proposed airflow control devices shall include discharge, exhaust, and radiated sound power level performance obtained from testing in accordance with ARI Standard 880.

D. Performance Verification

The laboratory airflow control system supplier/manufacture shall demonstrate a typical laboratory space that includes multiple fume hoods, a general exhaust, and a supply airflow control device for the purpose of verifying the laboratory airflow control system's ability to meet the performance requirements indicated in this specification. All travel and lodging costs to witness the performance verification shall be the responsibility of the laboratory airflow control system supplier.

E. Preventive Maintenance

1. The laboratory airflow control system supplier/manufacture shall provide at no additional cost to the owner during and after the warranty period, five years of required preventive maintenance on all airflow sensors (e.g., pitot tube, flow cross, orifice ring, air bar, hot wire, vortex shedder, side wall sensors, etc.), and flow transducers provided under this section. Airflow sensors shall be removed, inspected and cleaned annually during the five year period to prevent inaccuracies due to long term buildup from corrosion, lab tissues, wet or sticky particles, or other materials that foul the sensor. The transducer shall be checked and recalibrated annually to insure long term accuracy.

F Airflow Control System Description

1. Each individual laboratory shall have a dedicated laboratory airflow control system.

2. The laboratory airflow control system shall employ constant volume dummy control valves for fume hood operation.

3. The laboratory airflow control system shall maintain specific airflow (± 5% of signal within one second of a change in duct static pressure) regardless of the magnitude of the pressure change (within 0.6" to 3.0" wc), airflow change or quantity of airflow control devices on the manifold.

6. The laboratory airflow control system shall use volumetric offset control to maintain room pressurization. The system shall maintain proper room pressurization polarity (negative or positive) regardless of any change in room/system conditions such as rapid changes in duct static pressure. Systems using differential pressure measurement or velocity measurement to control room pressurization are unacceptable.

7. The laboratory airflow control system shall maintain specific airflow (± 5% of signal) with a minimum 16 to 1 turndown to insure accurate pressurization at low airflow and guarantee the maximum system diversity and energy efficiency.

G. Airflow Control Sound Specifications

1. Unless otherwise specified the airflow control device shall not exceed the sound power levels in Table 1, Table 2 and Table 3.

2. All proposed airflow control devices shall include discharge, exhaust and radiated sound power level performance.

Table 1. Exhaust Airflow Control Device Sound Power Level

	Exhaust Sound Power Level in dB (re: 10^{-12} watts)					
Octave Band Number	2	3	4	5	6	7
Center Frequency in Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
1000-50 cfm Device						
800 cfm @ 0.6” wc	63	55	52	54	50	49
200 cfm @ 0.6” wc	46	42	38	37	32	25
800 cfm @ 3.0” wc	73	70	64	66	65	60
200 cfm @ 3.0” wc	51	52	51	50	52	51
1500-100 cfm Device						
1200 cfm @ 0.6” wc	65	58	53	56	52	52
400 cfm @ 0.6” wc	50	45	38	39	37	31
1200 cfm @ 3.0” wc	72	70	62	65	64	60
400 cfm @ 3.0” wc	55	57	55	53	56	55
3000-200 cfm Device						
2400 cfm @ 0.6” wc	63	56	55	58	54	55
800 cfm @ 0.6” wc	51	45	41	42	39	34
2400 cfm @ 3.0” wc	75	71	65	68	67	63
800 cfm @ 3.0” wc	58	58	56	56	59	58

Table 2. Supply Airflow Control Device Sound Power Level (Discharge)

	Discharge Sound Power Level in dB (re: 10^{-12}					
Octave Band Number	2	3	4	5	6	7
Center Frequency in Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
1000-50 cfm Device						
800 cfm @ 0.6” wc	62	57	54	58	54	51
200 cfm @ 0.6” wc	45	46	42	44	40	34
800 cfm @ 3.0” wc	72	71	67	75	72	68
200 cfm @ 3.0” wc	53	56	54	58	56	54
1500-100 cfm Device						
1200 cfm @ 0.6” wc	63	59	55	60	54	53

400 cfm @ 0.6" wc	53	49	44	49	45	39
1200 cfm @ 3.0" wc	72	73	69	77	72	68
400 cfm @ 3.0" wc	58	63	61	63	60	57
3000-200 cfm Device						
2400 cfm @ 0.6" wc	64	60	58	63	56	56
800 cfm @ 0.6" wc	52	48	47	52	46	41
2400 cfm @ 3.0" wc	75	75	72	78	73	70
800 cfm @ 3.0" wc	59	62	62	66	62	60

Table 3. Supply Airflow Control Device Sound Power Level (Radiated)

	Radiated Sound Power Level in dB (re: 10^{-12}					
Octave Band Number	2	3	4	5	6	7
Center Frequency in Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
1000-50 cfm Device						
800 cfm @ 0.6" wc	44	41	45	41	36	34
200 cfm @ 0.6" wc	33	28	31	29	26	20
800 cfm @ 3.0" wc	53	53	56	57	55	53
200 cfm @ 3.0" wc	41	38	41	39	39	37
1500-100 cfm Device						
1200 cfm @ 0.6" wc	47	53	40	42	38	36
400 cfm @ 0.6" wc	35	39	31	34	33	26
1200 cfm @ 3.0" wc	52	60	54	60	59	53
400 cfm @ 3.0" wc	42	44	43	46	46	42
3000-200 cfm Device						
2400 cfm @ 0.6" wc	58	56	45	47	43	42
800 cfm @ 0.6" wc	45	43	36	39	37	29
2400 cfm @ 3.0" wc	69	68	60	65	63	57
800 cfm @ 3.0" wc	54	53	48	51	50	48

H. Airflow Control Device – Fume Hood

1. The airflow control device shall be a constant volume venturi valve with no controls.

2. Certification
   a. Each airflow control device shall be factory calibrated to the job specific airflows as detailed on the plans and specifications using NIST traceable air stations and instrumentation having a combined accuracy of at least ± 1% of signal over the entire range of measurement. Electronic airflow control devices shall be further calibrated and their accuracy verified to ± 5% of signal at a minimum of eight different airflows across the full operating range of the device.

b. All airflow control devices shall be individually marked with device specific, factory calibration data. As a minimum, it should include: tag number, serial number, model number, eight point characterization information (for electronic devices), and quality control inspection numbers. All information shall be stored by the manufacturer for use with as-built documentation.

I. Airflow Control Device – Supply & Exhaust

1. The airflow control device shall be an airfoil bellows type.

2. Provide factory mounted pneumatic operated valves with unit mounted vortex type air flow sensors and transmitters by unit manufacture. Valves shall be capable of two position, variable volume or constant volume operation as indicated on drawings.

3. The Vortex-SD airflow transmitter shall consist of multi-sensor probes in a pre-assembled airflow station mounted on the air valve assembly. Individual sensors shall provide pulse outputs which are directly proportional and linear to airflow velocity. These digital signals shall be totalized in the companion transmitter and converted to a 4-20 mA output, linear to follow. Accuracy shall be $\pm$ 1.5% FS for flows above 500 FPM. Velocity range shall be 350 to 2000 FPM.

4. Sensors shall be 304 stainless steel for supply & exhaust and 316L stainless steel for all fume hood, canopy and snorkel applications. Single point sensors are not acceptable.

5. Airfoil and Vortex assembly shall be capable of maintaining accuracy when mounted with inlet and outlet 90° elbows. The airfoil valve shall be "fail-safe" to fail in the open position for exhaust and closed position for supply unless indicated otherwise on the drawings.

6. The control device shall regulate flow based on a varying 0 to 10 volt electronic signal and a varying 8 to 13 psi pneumatic signal. The VAV purpose devices requiring flow feedback shall generate a 0 to 10 volt feedback signal that is linearly proportional to its airflow.

7. Suppliers of airfoil valves or airflow measuring devices requiring minimum duct diameters shall provide revised duct layouts showing the required straight duct runs upstream and downstream of these devices. Coordination drawings reflecting these changes shall be submitted by the supplier of the laboratory airflow control system. In addition, suppliers shall include static pressure loss calculations as part of their submittals. All costs to modify the ductwork, increase fan sizes and horsepower, and all associated electrical changes shall be borne by the laboratory airflow control supplier.

J. Laboratory Control Unit

1. A laboratory control unit shall control the supply and/or general exhaust airflow control devices to maintain proper room pressurization polarity (positive or negative). Each individual laboratory shall have a dedicated laboratory control unit.

2. The control unit shall be electronic. The inputs shall accept linear feedback signals from fume hood, canopy and snorkel airflow control devices. The output signals shall control supply, general exhaust/return airflow control devices and/or variable frequency drives with signals that are linearly proportional to the desired supply or exhaust airflows.

3. The control unit shall maintain a constant design offset between the sum of the room's total exhaust and make-up/supply airflows. This offset shall be field adjustable and represents the volume of air which will enter (or exit) the room from the corridor or adjacent spaces.

4. The control unit shall provide linear signals that are proportional to all airflow sources, sash sensors, and flow alarms. The signals shall be available for hard wired connection to the facility's direct digital control (DDC) system.

5. The laboratory control unit shall be panel mounted.

6. Refer to the control drawings for points required for input/output necessary to monitor and or control.

7. Each laboratory shall have a dedicated standby 120 Vac line connection to power the laboratory's airflow control system power supply.

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. Conduit to be properly supported and sized at a maximum of 40% fill. In no case shall field installed conduit smaller than ½ inch be allowed. 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.
   a. Prior to installation, 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. Mounting of field microprocessors on air handling units is not acceptable.

3.05 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.

3.06 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.
1. Final adjustment performed by specially trained personnel in direct employ of manufacturer of control system.

3.07 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 start-up, adjustment & testing report on all systems before system verification is begun.

B. Comply with USM IDAT in spec 01810.

3.08 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.

3.09 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.

3.10 SEQUENCE OF OPERATION

A. Convectors: Provide wall mounted temperature sensor (adjustable). Sensor shall modulate a two-way hot water control valve to maintain space temperature set point.
1. Occupied Control: Space temperature set point 70°F.
2. Unoccupied Control: Space night setback temperature set point 60°F.

B. Server Room ACU-2 & ACU-3 and Electrical Room ACU-4:

1. Occupied Mode:
   a. On a rise in space temperature above 72°F (adjustable), space sensor shall energize air conditioning unit ACU-x and air cooled condenser ACC-x. Fall in temperature, the reverse shall occur.
   b. Interlock air cooled condenser ACU-x with air conditioning unit ACU-x.

2. Safety Controls:
   a. Motor current transducer signal below set point deenergize fan and alarm DDC system.

C. Air Cooled Water Chillers CH-3:

1 Chiller start/stop from a signaled from the DDC System based on a rise in outside temperature above 53°F. The lead chiller isolation valve shall modulate open, once flow is proven lead chiller shall energize. The chiller unit mounted controller shall modulate chilled water capacity to meet set point based on supply and return water temperature sensors inputs through the DDC system. DDC system shall monitor all specified points and control temperature set points, reset temperature schedules, on/off control, etc., through the chiller manufactures BACNET gateway. Alternate chillers based on run time or failure.

D. AHU-4 (3rd. 4th & 5th Floor Labs)

1. Safety Controls

a. Install smoke detector downstream of the air filters and ahead of any branch connections in main supply ducts. Duct smoke detectors provided by the Electrical Contractor and installed by Mechanical Contractor. Provide the necessary wiring from the smoke detector to the supply fans. Upon detection of smoke the supply fans shall be de-energized and alarm signal sent to the DDC system.
b. Provide freezestat and install serpentine across leaving side of steam coil. De-energize unit fan when discharge temperature falls to 32 deg.F, close outside air damper, modulate steam control valve full open and alarm DDC system.
c. Provide relays to close outside air damper when unit fan is de-energized and send alarm signal to the DDC system.
d. Provide current relays for supply fan motors. When signal is below set point, de-energize fans and send alarm signal to the DDC system.
e. Provide differential pressure sensor across filter media.
f. Provide vibration transmitter/switch at supply fan. When signal is above set point of the fan/vibration isolation assembly shut down fan and alarm DDC system.

2. The design for 100% outside air handling unit intake dampers, recovery coil, steam heating coil with integral face and bypass, chilled water cooling coil, supply fan, fan vibration switch, isolation dampers, variable speed drives.

a. Systems shall be scheduled through the DDC for start/stop operation. On occupied mode start-up the outside air damper shall open and the supply fan shall start.

2. Startup and Fan Shutdown:

a. When unit is indexed to start, outside damper shall modulate full open, energize supply fan and program interlock exhaust fans (EF-19, EF-20 & EF-21) to start if not already running.
b. Whenever supply fan is de-energized, outside air dampers close, smoke dampers closed, and steam valve shall modulate to maintain a casing temperature above 45°F.

3. Fan/motor Failure:

a. Upon a motor or fan failure of the air handling unit, close outside air damper modulate steam coil to maintain a minimum 45°F case temperature, chilled water control valve closed, alarm DDC system upon fan failure.

4. Temperature Control:

General:

a. A supply duct air sensor through DDC system shall maintain a constant discharge air temperature of 55°F (adjustable).
b. The energy heat recovery coil shall not be operable when the ambient temperatures are between 55 °F (adjustable) and 75 °F (adjustable).

Heating

a. Upon a drop in the discharge air temperature set point, the energy recovery control valve shall modulate open to maintain set point. If the energy recovery control valve is 100% open and the discharge air sensor is below set point, the steam heating coil control valve shall open fully. The integral face & bypass damper shall modulate open to maintain set point. When the discharge air sensor rises above the set point, the reverse shall occur.

Cooling:

a. Upon a rise in the discharge air temperature set point, the cooling coil control valve shall modulate open to maintain set point. When the ambient temperature reaches 84°F, the energy recovery coil control valve shall fully open and the cooling coil control valve shall modulate to maintain set point.

5. Static Pressure Control:

a. The DDC Controller shall measure duct static pressure and shall in turn modulate the variable frequency drive (VFD) to control for the system static pressure set point. The control system shall monitor the various static pressure points and control to satisfy the worst case. Duct static pressure tap locations are to be far enough out in the system to allow the plenum static pressure to vary with overall system flow.

E. FUME EXHAUST HEAT RECOVERY UNIT (EF-19, 20, 21 & FEU -2)

1. Fans Start/Stop: The fans will be signaled to start/stop through building DDC system.

2. Static Control:
   a. Two static pressure sensors shall be with the main exhaust duct(s) as indicated on contract drawings.
   b. Under minimum static condition one exhaust fan shall be running at all times.
   c. The DDC Controller shall measure duct static pressure and shall in turn modulate the variable frequency drive (VFD) to control for the system static pressure set

point. The control system shall monitor the various static pressure points and control to satisfy the worst case. Duct static pressure tap locations are to be far enough out in the system to allow the plenum static pressure to vary with overall system flow.

d. The system shall also measure airflow and maintain a minimum discharge velocity of 3000 fpm by staging fans on and off. The VFD minimum speed pot shall be set during system startup and balancing to ensure that the discharge velocity cannot be decreased below the minimum.

e. The system shall start with one fan running and the VFD at full speed. The DDC Control Panel shall control the system static pressure set point by measuring the static pressure in the duct and modulating the VFD to maintain the static pressure at its set point. If the duct static pressure rises above the set point, the DDC Control Panel shall modulate the VFD speed down to decrease the duct static pressure. If the duct static pressure decreases below the set point, the DDC Control Panel shall modulate the VFD speed up to increase the duct static pressure.

f. If the duct static pressure set point cannot be maintained with one fan running and the VFD at maximum speed, the DDC Control Panel shall command the next fan on and modulate the VFD(s) to maintain the duct static pressure set point. A time delay will be set in the DDC Control Panel to allow the system to stabilize before starting or stopping additional fans.

g. If the duct static pressure increases above the setpoint while multiple fans are running, the DDC Control Panel shall modulate all VFD’s down together to maintain the setpoint, until the minimum velocity and speed is reached, while maintaining the minimum discharge velocity of 3,000 fpm.

h. If the duct static pressure set point cannot be maintained with the multiple fans running and the VFD at minimum speed and fan discharge velocity, the DDC Control Panel shall command one fan off and modulate the VFD speed up to maintain the duct static pressure set point.

I. If the duct static pressure falls below or exceeds the set point for a period of time in excess of an adjustable alarm delay period, a static pressure alarm condition shall be indicated to the DDC Control Panel and made available to the BMS. If a loss of static pressure results from the failure of an exhaust fan, the standby exhaust fan shall automatically be energized.

3. Exhaust Fan Control:

a. Each exhaust fan motor shall have a Hand-Off-Auto Switch on its VFD. When the 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), the fan shall be enabled for control by the DDC Control Panel and shall be controlled as described in the following paragraphs.

b. Each exhaust fan shall have a normally closed, spring return isolation damper upstream of the inlet. After an exhaust fan is commanded on, the isolation damper associated with the fan 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 an exhaust fan is commanded off, the isolation damper shall automatically close. (Note: The fans have a non-stall characteristic and can run against a fully closed damper.)

c. Proof of exhaust fan operation shall be indicated to the DDC Control Panel by current sensing on each individual fan. A variation from current draw limits on a running fan shall constitute an exhaust fan failure alarm at the DDC Control Panel. Upon an equipment failure condition which results in an exhaust fan failure alarm, the DDC Control Panel shall immediately command the standby exhaust fan on. If all fans are running due to system demand and a fan fails, the DDC Control Panel will lock out only the failed fan while leaving the other fans in operation. A display on the DDC Control Panel indicates which fan has failed and a remote set of contacts will close to the BMS.

4. Minimum Discharge Velocity Control

a. Under minimum static condition one exhaust fan will be running at all times.

c. If the duct static pressure increases and the air flow measuring station indicates the discharge velocity is falling below 3,000 fpm the DDC controller shall in turn modulate the outside air bypass damper(s) *(normally closed, spring return)* to maintain the minimum discharge velocity at its set point. Upon a 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.

d. If the duct static pressure set point cannot be maintained and the discharge velocity falls below 3,000 fpm for a period of time in excess of an adjustable alarm delay period, a static pressure/velocity alarm condition shall be indicated to the DDC Control Panel. If a loss of static pressure/minimum velocity results from the failure of an exhaust fan, the standby exhaust fan shall automatically be energized.

5. Fan Wear Equalization

a. To ensure run time equalization the first fan to be turned on will be the first fan to cycle off, the last fan turned off will be the first to cycle back on. Each fan should operate for at least one hour per week.

6. Heat Recovery Temperature Control

Winter

a. When the ambient temperature is below the 55 °F, the exhaust energy recovery coil control valve shall fully open. When the ambient temperature is at 55 °F or above, the exhaust energy recovery coil control valve shall fully close.

Summer:

b. When the ambient temperature is at or above 84 °F, the exhaust energy recovery coil control valve shall fully open. When the ambient temperature is at below 84 °F, the exhaust energy recovery coil control valve shall fully close.

7. Glycol Circulating Pump (P-6, P-7, & P-8) Control

a. The energy recovery pumps P-6, P7, P-8 shall operate in a lead/lag/standby. The BAS system shall alternate the lead/lag/standby on a weekly basis.

b. The pump VFD shall modulate the lead pump motor speed to maintain the differential pressure set point. Pump speed shall be increased in response to a decrease in differential pressure. Pump speed shall be decreased in a response to an increase in differential pressure. If system differential pressure continues to fall when the lead pump has reached 95-percent of its full motor speed, the lag pump shall be activated. Both pumps shall then be modulated in unison to maintain system pressure. If both pumps are operating at minimum speed (approx. 35% of full motor speed) the differential pressure rises above set point, one pump shall be de-activated. The single pump shall be modulated to maintain differential pressure.

c. The water system initial set point shall be 15 PSI. This value shall be adjusted to the required set point to achieve the proper flow rate as determined during balancing. Provide 2 PSI dead band to prevent short cycling.

d. If the lead pump fails as determined by its current transmitter, the lag pump shall start.

E. LABORATORY AIRFLOW CONTROL

1. General:

a. All set points Bias shall be adjustable through BMS operator interface.

b. Should a failure of normal power be sensed, all supply & general exhaust air valves shall return to their closed position.

c. Laboratory Set points:

Heating = 70 °F

Cooling = 72 °F

2. Supply Airflow Control:

a. The laboratory is served by a variable volume airflow valve with a duct mounted hot water coil.

b. The supply airflow rate shall modulate between the valve's minimum and maximum flow rates (refer to schedule sheet) in response to the laboratories space temperature requirements.

3. Exhaust Airflow Control

a. Fume Hood: The exhaust airflow for the fume hood shall be controlled through the use of a constant volume venturi exhaust valve.

b General Exhaust: The laboratory general exhaust valve shall be automatically modulated to maintain the required supply/exhaust air volumetric. The BMS system shall continuously monitor the supply airflow rate and calculate the required exhaust flow rate (Supply airflow – (Transfer CFM + Fume Hood CFM)). This set point shall be used in resetting the general exhaust valve flow rate. The general exhaust valve shall not operate below its minimum airflow set point indicated on the schedule drawings.

4. Temperature Control:

a. As the space temperature rises 0.5°F above its cooling set point, the BAS system shall increase the quantity of supply air to the space as required to maintain space temperature.

b Outside Air Temp Below 60°F: As the space temperature drops 0.5°F below it heating set point and the outside air temperature is below 60°F, the BAS system shall decrease the quantity of supply air to its minimum set point and modulate the hot water fin tube radiation control valve open to maintain space temperature. If the space temperature drops 1°F below set point, the BMS system shall then modulate the hot water reheat control valve open to maintain space temperature.

c. Outside Air Temp Above 60°F: As the space temperature drops 0.5°F below it heating set point and the outside air temperature is above 60°F, the BAS system shall decrease the quantity of supply air to its minimum set point and modulate the hot water reheat control valve open to maintain space temperature.

5. Alarms:

a. High Space Temperature: If the space temperature rises 2 °F above the cooling set point for more than 30 minutes, an alarm shall be issued at the DDC system.

b. Low Space Temperature: If the space temperature drops 2 °F below the cooling set point for more than 30 minutes, an alarm shall be issued at the DDC system.

F. OFFICE AIRFLOW CONTROL

1. General:

a. All set points Bias shall be adjustable through BMS operator interface.

b. Should a failure of normal power be sensed, all supply, return and general exhaust air valves shall return to their closed position.

c. Office Set points:

Occupied	Un-Occupied
Heating = 68 °F	Heating = 60 °F
Cooling = 74 °F	Cooling = 80 °F

2. Supply Airflow Control:

a. The office areas are served by a variable volume airflow box with an integral hot water coil.

b. The supply airflow rate shall modulate between the boxes minimum and maximum flow rates (refer to schedule sheet) in response to the office space temperature requirements.

3. Exhaust Airflow Control (4^{th} & 5^{th})

a General Exhaust: The office space general exhaust valve shall be automatically modulated to maintain the required supply/exhaust air volumetric. The BMS system shall continuously monitor the supply airflow of multiple air boxes (indicated on plans) calculate the required exhaust flow rate (Total Supply airflow – (Transfer CFM + Pressurization CFM)). This set point shall be used in resetting the general exhaust valve flow rate. The general exhaust valve shall not operate below its minimum airflow set point indicated on the schedule drawings.

4. Temperature Control: (occupied)

a. As the space temperature rises 1°F above its cooling set point, the BAS system shall increase the quantity of supply air to the space as required to maintain space temperature.

b Outside Air Temp Below 60°F: As the space temperature drops 1°F below it heating set point and the outside air temperature is below 60°F, the BAS system shall decrease the quantity of supply air to its minimum set point and modulate the hot water fin tube radiation control valve open to maintain space temperature. If the space temperature drops 1.5°F below set point, the BMS system shall then modulate the hot water reheat control valve open to maintain space temperature.

c. Outside Air Temp Above 60°F: As the space temperature drops 1°F below it heating set point and the outside air temperature is above 60°F, the BAS system shall decrease the quantity of supply air to its minimum set point and modulate the hot water reheat control valve open to maintain space temperature.

5. Temperature Control: (Un-occupied)

a. Morning Warmup/Cooldown: VAV box shall be reverse acting on warm-up and under control of local space sensor on cool down.

b. When the office space is in un-occupied mode, the variable air volume box shall modulate closed, and space temperature shall be modulate the fin tube radiation control valve open to maintain un-occupied space temperature.

6. Alarms:

a. High Space Temperature: If the space temperature rises 2 °F above the cooling set point for more than 30 minutes, an alarm shall be issued at the DDC system.

b. Low Space Temperature: If the space temperature drops 2 °F below the cooling set point for more than 30 minutes, an alarm shall be issued at the DDC system.

G. Toilet Exhaust Fans:

1. Program operating periods for fan to run based on DDC system.
2. When exhaust fan(s) start, motor operated exhaust damper shall open.
3 When fan(s) are off, motor operated exhaust damper shall close.
4 Motor current relay signal below set point de-energize fan and alarm DDC system

H. Tel-Data Room Exhaust Fans:

1. Upon a space temperature greater than 80°F, a signal from the space temperature sensor energizes the fan and modulates the motorized dampers open.
2 When fan(s) are off, motor operated damper shall close.
3. Motor current relay signal below set point de-energize fan and alarm DDC system

I. Boiler:

1. Upon a loss of heat exchanger primary steam pressure or during a scheduled maintenance shut-down the summer/backup boilers will automatically start. The boiler will be energized only if there is proof of water flow at the pumps.

3.12 START-UP, ADJUSTMENT, & TESTING

A. Start-up, adjustment & testing the Facility Management System is a mandatory documented performance requirement of the selected CONTROLS Contractor for all control systems detailed in this Specification and sequence of operations. Start-up, adjustment & testing 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 start-up, adjustment & testing step and final completion to ensure proper operation of the

Facility Management System. Owner is providing a separate independent start-up, adjustment & testing contractor in addition to the start-up, adjustment & testing requirement by the CONTROLS contractor.

B. Acceptance Check List

1. An acceptance checklist shall be completed that documents compliance with each item of this Specification.

C. Testing Procedure

1. 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

1. 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.

E. Comply with USM IDAT per section 01810.

3.13 NOT USED

3.14 LABORATORY AIRFLOW CONTROL SYSTEM INSTALLATION

A. The CONTROLS contractor shall install the laboratory control unit and wall-mounted power supply in locations shown on Architectural Plans in the designated laboratory rooms.

B. The CONTROLS contractor shall terminate and connect all cables as required. In addition, integrated laboratory control unit connectors shall be furnished by the Controls Contractor.

C. The mechanical contractor shall install all airflow control devices in the ductwork and shall connect all airflow control valve linkages.

D. The mechanical contractor shall provide and install all reheat coils and transitions.

E. The mechanical contractor shall provide and install insulation as required.

F. The ATC contractor shall wire a dedicated, single phase 120 vac power circuit to the laboratory control unit or power supply.

G. System Start-up and Training

1. System start-up shall be provided by a factory authorized representative of the laboratory airflow control system manufacturer. Start-up shall include calibrating the fume hood monitor and any combination sash sensing equipment as required. Start-up shall also

provide electronic verification of airflow (fume hood exhaust, supply, make-up, general exhaust, or return).

2. The balancing contractor shall be responsible for final verification and reporting of all airflows.

3. The laboratory airflow control system supplier/manufacture shall furnish a minimum of forty hours of on-site owner training, by factory trained and certified personnel. The training will provide an overview of the job specific airflow control components, verification of initial fume hood monitor calibration, general procedures for verifying airflows of air valves, and general troubleshooting procedures.

4. Operation and Maintenance manuals, including as-built wiring diagrams and component lists shall be provided for each training attendee.

END OF SECTION 15910