SECTION 15970 - "AUTOMATIC CONTROL AND MONITORING SYSTEMS"

1.0 All systems in excess of 7-1/2 tons (packaged and split type included) shall be controlled via an electronic control system interfacing with the existing campus **Energy Management System** (EMS) central control. The electronic controllers shall be provided by one of the following automation equipment/system suppliers: Allen Bradley, Johnson Controls Inc., Moore APACS, Siemens Building Technology, and Automatrix.

2.0 In general, each project shall require that the Mechanical Contractor or subcontractor shall engage an authorized Controls Subcontractor to furnish, install, wire, guarantee and service the entire electronic control system. The controls subcontractor shall also be required to coordinate the selection installation and wiring of all components required for integration into the existing Campus Operation Control Center (OCC) Building Automation Control (BAC) system.

3.0 Pneumatic devices shall be limited to the following components:

A. E.P. and P.E. switches
B. Damper and valve actuators
C. Pilot positioning devices
D. Current-to-Pneumatic transducers (I/P)

Electronic motors may be substituted and used as valve and damper actuators provided they meet the torque requirements for closing/opening the device against the system pressure and the response of such is adequate to maintain desired conditions of process variable.

4.0 All new pneumatic systems shall include duplex compressors each, adequately sized to handle 80% of the anticipated peak load, compressor alternating controls to assure equal run time, a pneumatic tank sized to provide minimum storage capacity of 2 hours in the event of power loss and a mechanical filter dryer system capable of reducing the dew point temperature of the air to +20^{o}F at a pressure of 25 PSIG. An investigation of the existing buildings air system shall be completed and assessed prior to the addition of new components. No pneumatic tubing will be installed exposed to the elements or where it could be subject to freezing. Connection to existing control air source air should be approved by a University representative and designing engineer. Their systems will include duplex reducing stations.

5.0 All pneumatic tubing shall be run in Type "L" (high pressure) hard copper with soldered joints (95-5 solder). Compression type connections are permitted at connections to equipment only. Minimum tubing size shall be 1/4"0.025" wall thickness. Tubing shall be run in open conduits with a minimum of 20% available for spares. Tubing shall be identified at panel drops and end devices. Copper tubing connections to end devices will utilize barb connections to plastic tubing.

6.0 All control valves (chilled, condenser, hot water and steam) shall be of the throttling plug (water) or V-port (chilled water choke valve) repacking type. Valves 2" and smaller shall have threaded brass bodies. Valves shall have unions installed before and after for service. Valves above 2" shall be flanged and have cast iron bodies. All valves shall be provided with stainless steel stems and trims, seats, plugs, etc. Plug types as follows:

A. Steam - Linear characteristic – 1/3-2/3.
B. Modulating chilled water service - Equal percentage plug.
C. Modulating hot water service- linear characteristic.
D. Two position - Flat seat/quick opening.

7.0 Each project shall provide control panels in the quantities and locations necessary to properly access and house all control equipment. Panels shall be provided with hinged covers and key operated locks. Top conduit access to any panels is prohibited. Panel should be located in a dry location and accessible from the floor level. All control panel locations shall be pre-approved by a representative of Facilities Operations. All control panels shall be located on the project coordination drawings. Refer to *Section 15010*. The A/E shall indicate all control panel power requirements on the contract drawings.

8.0 Prior to the design of the integration into the central control and monitoring system the A/E shall arrange a meeting with the University Engineer to discuss and resolve the following:

A. Minimum required control points list and the points monitored and/or controlled by central **EMS** at the **Operations Control Center (OCC)**.

B. Available capacity of existing DDC panels and nodes for connection to EMS- SCADA.

C. Required system diagrams, flow and control diagrams and ATC/P&ID diagrams are required. Review of submittals must be conducted via a meeting with the University Engineer prior to approval.

D. Process & Instrumentation Drawings.

E. How the respective system dynamic information is reported back to the existing campus Operations Control Center (OCC). For new installations only, a network connection into the building subnet along with IP address, hostname, net mask address and default route address. These are required to get the system data from the new location to OCC.

9.0 The drawings and specifications shall, as a minimum, include the following requirements:

A. General system description, system architecture, including sequence of operations, point listing, description and type, engineering units, calibration, etc.

B. Shop drawing submittal requirements, including the following:

C. Drawings:

1. Contractor shall provide as a minimum, individual drawing for each system.

2. Drawings shall show all system hardware, distributed Processing Unit, (DPU's), field devices, electrical work as well as all ATC work with each drawing containing the following information:
   a. Wiring type and method of installation.
   b. Control tubing information.
   c. Point numbers and termination numbering for each DPU.
   d. Detailed Bill of Material with appropriate reference to section where product data is presented.
   e. Sequence of operation. Including P&ID (Control) diagrams.
   f. Hardwired, Calculated and Logical Point database listing, software addresses following nomenclature in appendix, wiring numbering, control/alarm, set points, and termination locations.

D. Hardware:

1. The Contractor shall furnish complete documentation pertaining to hardware and all other equipment supplied. (including power requirements per control panel).

2. Contractor shall document all point connections at the Data Gathering Panels. Include all pertinent wiring, field device, hardware, termination modules and software data. Locations of DDC panels are to be coordinated with the University Controls Engineer.

3. Contractor shall document all I/O point cards (modules) and communication cards installed in Data Gathering Panels. Include all pertinent data, including firmware/software versions, switch settings, and calibration data.

E. Software:

1. Provide the following information pertaining to DPU software:
   - All programs pertinent to project and backup format with software used to create backup.
   - Operating system software on CD or other magnetic media.
   - All software, hardware and licenses required to operate, maintain and modify the system controls.

F. Data Base:

1. Contractor shall submit point data input forms and samples of all operator terminal formatted input screens with descriptions of each input.
2. See the end of this section for examples.

G. Graphics:

1. List of color graphics screens being provided.
2. System graphics and controls graphics with the location and areas served.
3. Proposed format of each color graphic screen being provided including point data displayed dynamically.
4. Graphics must be approved by Operations prior to installation.

*H. Provide the following information pertaining to Distributed Processing Units (**DPU**) software:*

General:

a. List all software packages provided with each DPU.

b. Indicate the DPU software that will execute at the DPU independent of the Central Control Unit (CCU), the transmission link to the Central Control Unit (CCU) or other DPUs.

Direct Digital Control (**DDC**) Software:

a. List of all control loops being provided.

List of the Process Control Language instruction set including a definition each instruction.

b. Listings of Direct Digital Control routines that the Contractor will use to implement the sequence of operations specified.
An English explanation of the meaning is located on each line of the DDC code. This explanation shall be detailed and include

definitions of each variable and instruction contained in the line code.

A list of the software points to be used to implement each set point and control PID tuning parameters, and any other software points used.

A list of all variables and their meaning.

A flow chart and step diagram, for each DDC routine that will allow comparison with the Sequence of Operation being modeled. Each block of the flow chart should represent no more than one line of DDC code. It shall be possible for a person not familiar with the Process Control Language to use the flow charts to verify that the DDC code will perform the sequences as specified.

A list of the DDC routines provided in each DPU and their storage requirement.

A flow chart showing the interaction of DDC routines in each DPU including variables being transferred from routine to routine.

I. Description of Points:

1. Provide table(s) listing all points with item number as shown and the following:
    a. Respective DPU card/slot for each DPU and/or data gathering.
    b. Provide for all software points the following:

2. **Point name.**
3. **Point function** (should include calculated points and also logical (virtual) points available through a digital interface (not hardwired).
4. **Alarm limits.**
5. **Engineering Units**
6. **Device range in engineering units**
7. **Field Devices:**
    a. Specification data sheets including accuracy, calibration, and servicing information and quantities for all field devices.
    b. Tabulated information showing point number, field device, and data sheets reference for all points.
    c. Drawings of all local control panels (LCPs) including panel face layouts.

8. **Electrical Work:**
    Submit data sheet on each type of wire to be used and it's specific job application (e.g. Signal Wiring, Communication, Data Communication, etc.).
9. **Controls:**

a. Product data sheets including catalog information listing calibration and servicing for all equipment and devices.

10.0 Electrical Work Requirements:

A. General:

1. Wiring of all field devices and electrical devices to Local Control Panels (LCP) and Distributed Processing Units (DPU).
2. All communication wiring from existing EMS/SCADA to new DPUs.
3. All wiring of LCPs including but not limited to EP’s, I/P's, VPTs, DPTs, pilot lights, relays, transformers and other miscellaneous devices as shown and specified.
4. All power wiring (120 VAC) of field devices as required.
5. All miscellaneous control wiring.
6. All field devices, indoor and outdoor, except Room Temperature Transmitters shall have conduit connections made to them from junction boxes, with a minimum of 18 inches of flexible metallic conduit ("Greenfield") (liquid tight for devices outdoors or otherwise exposed to moisture) with sufficient slack to allow for removal and/or servicing.

B. Signal Wiring:

1. Signal wiring to all analog field devices, including but not limited to temperature transmitters (TT) (other than resistance temperature detectors (RTD)), humidity transmitters (HT), current to pneumatic (I/P) transducers, shall be twisted, 100% shielded pair, minimum 18 gauge wire with PVC cover Belden #8760. Wires are to be separate from any other wiring above 30 volts and shall be run in conduit with no splices, terminal strips/blocks.
2. Signal wiring to RTDs shall be as listed above, except shall be three (3) conductors Belden #8770.
3. Signal wiring to digital field devices (for circuits of 30 VAC or less) shall be as specified herein below for Low Voltage Control Wiring. No splices, terminal strips/blocks.
4. Signal wiring shield shall be grounded at DPU end only.

C. Communication Wiring:

1. Communication wiring shall be minimum three individually 100% shielded pairs (i.e. six conductors), minimum 18 gauge cable with overall PVC cover Belden #9773 or approved equivalent product of other manufacturers, run in conduit with no splices, separate from all

wiring over 30 volts. Shield shall be terminated as recommended by DPU manufacturer. Contractor shall notify Owner/Engineer in writing within 60 days after award of contract if this is in conflict with shield termination recommended by the CCU or DPU manufacturer. The contractor may use fiber Optic cable or other type of wiring after review and approval by OCC or the University Engineer.

2. In addition to the requirements specified above, all communication wiring cables shall include a 100% redundancy shielded pair (two conductors) as unused spare conductors. Where the number of conductors and specific cable specified above for each type of communication wiring will not meet this requirement for spare conductors, Contractor shall provide prior to installation approved equivalent product of Belden or other manufacturer with the necessary number of conductors and which meets the requirements specified above.

D. All wiring shall be provided in conduit. Rigid metal or intermediate metal conduit (IMC) in exterior locations, and mechanical room. Electrical metallic tubing (EMT – compression type) for all other interior installations) All devices and equipment shall be mounted in minimum NEMA 1 enclosures and NEMA 4 for mechanical rooms.

E. Low Voltage Control Wiring (30 VAC or Less):

1. Low voltage control wiring shall be minimum 16 gauge, twisted pair, 100% shielded with PVC over Belden #9316 or approved equivalent product of other manufacturers run in conduit with no splices, separate from any wiring above 30 volts.

11.0 Field Devices:

A. Temperature Transmitters (TT):

1. All temperature transmitters shall be resistance temperature detectors (RTD 4-20 MA) with 2-wire circuitry. However, wall mounted thermostats can be thermistor type or RTD. Wall mounted thermostats shall be sealed and insulated to prevent false readings. RTDs shall be platinum type (100 ohm at 32º F) or nickel-iron type (1,000 ohm at 70º F) as manufactured by Minco, and calibrated for the operating range of the measured variable.

2. Duct mounted insertion type RTDs (“RTD Duct Probe”) shall be rigid area averaging type, and shall include the sensing probe, holder, utility box and gasket to prevent air leakage and vibration noise. Minimum insertion depth shall be 80% of duct.

3. Bendable area averaging type RTDs ("RTD Duct Avg.") shall include the averaging sensor, utility box and gasket to prevent air leakage and vibration noise, and shall be used, as a minimum, in all mixed air and preheat air temperature applications. The mounting of the averaging RTDs shall be sufficient to cover the free area top to bottom. Each pass shall not exceed 12 in. from the previous pass. Minco model # S102339PE shall be used in applications less than 36 inches.
4. Fluid immersion-type RTDs ("RTD Pipe Well") shall be used for all hot, glycol, chilled, condenser water sensing points or any other fluid and shall include RTD probe, thermo wells, and temperature transmitters if required. Connection head probe and connection head shall be removable without breaking fluid seal or removing any equipment or piping. Fluid immersion RTDs shall be installed on the top of the pipe in horizontal runs and at a positive slope on vertical runs to prevent condensation from flowing to connection head. Small bore pipe should have thermo-wells installed at the elbows. All thermo wells shall be bottom third filled with heat conductive grease as manufactured by Dow Chemical. Thermo well shall be constructed of stainless steel and shall penetrate pipe to a minimum of 2/3 the pipe diameter.
5. End-to-end (i.e. measured temperature at field devices versus displayed valued in engineering units at DPU operator terminals and as displayed at CCU operator terminals) minimum accuracy of all TT's shall be +1.0 degree F over 100 degree F span, +0.5 degree F over any selected 20 degree F span and +0.25 degree F over any selected 10 degree F span.
6. Temperature transmitters sensing elements shall be provided in stainless steel case, epoxy sealed for moisture resistance (Minco model TT211, no exceptions).
7. All ATC devices should be installed to be accessible from the outside of the equipment, (AHU, etc.) served. Accessibility of all devices should be verified during the shop drawing review.
8. Temperature transmitters shall have the following ranges:
   a. AHU (air only) — 0 to 100 Deg. F.
   b. Chilled Water — 30 to 80 Deg. F.
   c. Condenser Water — 30 to 100 Deg. F.
   d. Hot Water Systems — 32 to 250 Deg. F.

B. Transducers:

1. Current-to-Pressure Transducers (I/P) - ("Cur/Press Tran"):
2. Current-to-pressure transducers Bellofram Type 1000, control air, or equal. All equals are to be pre-approved by Facilities Operations.

3. Current-to-pressure transducers shall have the following performance and application criteria:
   a. Supply Pressure 18 to 100 psig
   b. Output Pressure 3 to 15 psig
   c. Input Signal 4 to 20 milli-amp
   d. Independent Linearity + 1% F.S.
   e. Terminal Based Linearity + 1% F.S.
   f. Ambient Temperature -20 Deg. F. to 140 Deg. F.
   g. Hysteresis & Repeatability 1/4% F.S.
   h. Maximum Air Consumption 0.100 scfm
   i. Maximum Output Capacity 4.00 scfm

C. Humidity Transmitters (HT):

Units shall be suitable for duct or wall (room) mounting.
Unit shall be 2-wire transmitter with humidity sensor and shall operate on power requirements of 24V DC nominally unregulated. Unit shall produce linear continuous output of 4 to 20 MA for percent relative humidity (% RH). Sensors shall have the following performance and application criteria:

a. Input Range: 0 to 100% RH
b. Output Range: 4-20 MA
c. Accuracy (% RH): + 2% between 0 - 95% RH at 25 Deg. C.
d. Sensor Operating Range: -58 Deg. F. to 185 Deg. F; (Maximum operating temperature for wall mounted unit: 150 Deg. F).
e. Minimum zero and span adjustments of + 15% of full scale.
f. Vaisala model or equal. All equals are to be pre-approved by University of Pennsylvania controls engineer.

D. Differential Pressure Switches:

1. Differential pressure switches (for 2 psi) and below shall be diaphragm operated with minimum 3-1/2" diaphragm to actuate single pole double throw (SPDT) or double pole double throw (DPDT) as shown and required. DPS shall be UL listed with minimum 3% repetitive accuracy. DPS shall have set point screw adjustment with stainless steel calibration spring. DPS shall be Dwyer Series 1910 (SPDT Type) or 1627 (DPDT Type) or approved equivalent product of other manufacturer.
2. DPT for use on high-pressure application (above 2 psig) and water systems shall be UL listed and shall be as manufactured by Barksdale or Asco with appropriate range for the application. Provide DPT with snubbers and isolation valves on both input lines

(high and low) and with equalizing valve. DPS used on steam application shall be provided with pigtail siphon.

3. DPS shall be single or dual setting units as shown.

E. Electrical Interface Devices:

1. **Control Relays:**
   a. All control relays shall be UL listed with contacts rated for the application and mounted in minimum NEMA I enclosure.
   b. Control relays for use on electrical systems of 120 Volts or less shall be Pottor Brumfield Model KRPA or approved equivalent product of other manufacturer.
   c. Relays used for across the line control (start/stop) of 120V motors, 1/4 HP and 1/3 HP shall be rated to break a minimum 10 amp inductive load. Relays shall be Honeywell Model R4222D or approved equivalent product other manufacturers.
   d. Control relays for use on electrical systems greater than 120 volts shall be rated for 600 volts and shall be Allen Bradley Bulletin 70, Type N or approved equivalent product of other manufacturers.
   e. Tri-modal relays located at LCPs used for stop/start control shall have low voltage coils (30 VAC or less) and shall be provided with transient and surge suppression devices. These devices shall be Metal Oxide Varistors (MOV) or silicon avalanche diode (e.g. transform) with appropriate power dissipation and clamping voltage ratings.

2. **Control Transformers:**
   a. Furnish and install control transformers as required.

12.0 Refer to the Appendices herein for typical point identification diagrams.

13.0 *The project specifications shall define the provision for all drivers, gateways, and systems graphics necessary for complete system monitoring and operation.*

This section should identify the minimum system interface and interoperability expected between specific equipment controls and the DDC for each type of project, as well as the minimum number of graphic displays for each type of system.

In general, there is at least one system graphic for each major system (i.e. AHU, Hot water system, chilled water system) and at least one control graphic and one trend graphic for each system.

14.0 Existing University Campus Operations Control Center (OCC) – SCADA System:

The Building Automation Control (BAC) system provides monitoring and control of all buildings on the University campus and includes chiller plants and power sub-stations. The system is comprised of several different types of control hardware and field devices.
The control room operators interact with all control hardware through a single software package called QNX. This operator interface package communicates with all of the different control hardware and present information from each in a unified form to the operators. The operators manipulate controlled variables for any hardware from Process Vision.

The following table shows the current control hardware and communication protocol in use at the University.

Device	Protocol
Allen Bradley PLC5 / KT Card	DH+
Allen Bradley PLC5E	Ethernet (DH485)
Allen Bradley LOGIX	DH+
Carrier / RS-232	Proprietary
GE 90 70 PCIM	Proprietary
Siemens Building Technologies / RS-232	Open System Protocol (OSP)/Bacnet
Moore APACS	MBUS
Johnson Controls Inc. (NCM350)/NAE1	N1 Ethernet/Bacnet
American Automatrix	Proprietary (PUP)
Andover Controls	Bacnet

A. Comdale Technologies Inc developed process Vision. The information being requested in this document can be used by independent contractors or system integrators in conjunction with **Dick Engineering (416-391-2322 Contact for Dick Engineering is David Noel)**. **The subcontractor contractor must include the services of Dick Engineering within their bids to complete the systems integration to the University's systems.**

B. The BAC system at the University of Pennsylvania is a microcomputer-based system that interfaces with different types of control hardware distributed throughout the campus. Microcomputers located at various sites on campus act as database servers for sub-groups of control hardware devices. These database Operator Workstations are networked, and they allow data to be accessed from anywhere on the OCC for use in the monitoring and control of HVAC, Chiller Plant, and other equipment. The computer network uses the existing campus network cables. The various sub-networks are connected to the backbone. Different networking protocols can co-exist on the sub-networks, however only TCP/IP is allowed on PENN Network. The University of Pennsylvania Information and Computing Services (ISC) group strictly enforces this by configuring routers on PENN Network to pass only TCP/IP packets.

C. The HMI interacts with control hardware in the field through the QNX computer running as the database server and hardware specific Communication Interface or Device Driver. The Communication Interface reads data from the control hardware and writes it into the database. The Communication Interface also writes data from the database to the control hardware.

D. If a new communication driver is required, Dick Engineering should be contacted. Generally, the Contractor must provide the following for Dick Engineering to develop and install a communication driver for any new control hardware:

1. Complete communication protocol documentation that has a detailed technical description of how the protocol works, the format for messages, etc.
2. Access to technical personnel (by telephone or otherwise) who are knowledgeable about the protocol and be able to answer questions posed.
3. Access to test hardware or facilities for testing the Communication Interface.
4. Provision of technical personnel on-site at the University of Pennsylvania during the installation and verification of the Communication Interface.
5. Configuration of the control hardware to facilitate computer configuration.
6. Provision of any special interface card or software that is required.
7. Provision of the communication cable between the computer and the control hardware. The Contractor must ensure that a communication cable from the control hardware to the computer location exists, and that it is properly terminated. For example, serial cables may be terminated at the computer end with DB-9 or DB-25 female connectors. The location of the control hardware must be such that the cable length does not inhibit computer communication.
8. Completed data sheets with all of the variables configured on the control hardware.

9. The communication protocol should provide direct access to the control hardware as oppose to an intermediate device such as another computer supplied by the Contractor.

E. It is the responsibility of the system integrator to configure system graphics and control graphics for the new systems. Alarms to be configured into the system are defined in the sequence of operation as well as in the “Operations Center Building Alarm Standards for SCADA System Interface. Historical trending of all key analog data is to be provided.

15.0 Sequences of Operation – “General Operation”

A. **Sequence of Operation for AHU with Return Air**

Normal Conditions

Fan off outside; smoke/fan isolation and relief dampers closed; return dampers open. Reheat and chilled water valve closed (unless preheat or mixed air temp is below 45 deg. F. then chilled water valve would open). Humidity valve closed & Preheat valve modulating to maintain preheat set point (adj.)-(100%).

1. The fan will be started by the DDC (or by manual intervention through SCADA system). When supply fan is started return fan will start. Upon start command, minimum outdoor air Damper will open and if there is no minimum outdoor air damper, then the economizer damper will modulate to maintain minimum outside flow. The return and relief fan dampers will take corresponding position.

2. The fan shall maintain a discharge temperature of 55 deg (adj.). On a rise of discharge temperature above set point, the economizer damper shall modulate open, and then the chilled water valve will modulate open. When discharge air temp falls below set point then the reverse will occur. If outside wet bulb is greater then return wet bulb then dampers should go to minimum position and modulate chilled water valve to maintain discharge set point.

3. A static pressure sensor in mixed air plenum shall modulate open return air damper to maintain set point (adj.).

4. Outside air damper will also be modulated by a mixed air controller low limit. When mixed air temperature goes lower than mixed air set point (Adj.), the supply air controller will be overridden and the outside damper will be modulated close and return damper open to maintain mixed air temp.

5. Supply fan will start at minimum speed (if the system is variable volume). Supply fan will maintain a static pressure set point. (Adj.). Via a static pressure probe located 2/3 down duct. (designer to select best sensor location per duct configuration to avoid measurement errors due to turbulence)

6. Return fan will be started at minimum speed and ramped up to maintain a CFM that is calculated by measuring supply fan CFM – a fixed CFM.

7. Humidity control using the return humidity sensor will modulate Humidity valve to maintain a return humidity set point (adj.) and use discharge humidity as a high limit controller.

8. Smoke detectors, via hard wired safeties, will stop the supply and return fans, close all dampers except the return damper, which will go open.

9. Engineer should add shutdown sequence and describe other safeties. Additional safety devices, including a hard wired freeze stat, may be required to maintain and shut down the AHU to protect system from a catastrophic failure.

B. **Sequence of Operation for Single Zone Classroom**

1. Supply-Fan Control: Scheduled occupancy program starts fan to run continuously during occupied periods. Depending on the season, Warm-Up or Cool-down modes may precede normal operation where the system operates on 100% re-circulation mode until it reaches the pre-set temperature limit and then attains minimum outdoor air and spill damper positions.

   a. A differential pressure switch across each fan will be used to determine the fan running status. If the fans fail to start, an alarm will be issued to the BAS.
   b. A low static pressure switch at the inlet of each fan and a high static pressure switch at the discharge of each fan are hardwired to shut down both fans if a static set point is exceeded. If a static pressure switch trips, a signal will be issued to the BAS indicating which fan has exceeded the static pressure limit.
   c. When the supply fan is started, the return fan will start and continue to run until the supply fan is stopped. Upon receipt of a signal from the FAP, it will be possible to run the return

fan alone with all dampers in the system closed except for the spill air damper, which will be open. The interlock with the FAP will be wired by others to a digital input on the Siemens MEC. The control of the fans and dampers in smoke mode will be through software command and will not be hardwired.

2. Freeze Protection: A duct mounted low limit detector mounted on the face of the cooling coil will trip on low temperature and signal an alarm to the BAS. The low limit detector is hard wired to shut down the supply and return fans, open the return air damper and cooling coil valve and close the outdoor air and spill dampers on a trip.
3. High Temperature Protection: A duct mounted return air temperature sensor will send an alarm to the BAS if the return air temperature rises above 95 degrees F.
4. Smoke Detection: Smoke detectors located in the supply and return air ducts signal an alarm, stop the supply and return air fans through hard wired interlock, close outside air and relief dampers, and open return damper when products of combustion are detected.
5. Preheat Coil Control: The glycol/hot water main circulator keeps running at all outdoor air temperatures below 45 degrees F (adj.) to maintain flow. When the outdoor air temperature falls below 45 degrees F (adj.), the local preheat coil circulator pump starts and the preheat coil valve is modulated to maintain the preheat coil discharge set point as measured by the preheat temperature transmitter. The pump shall shut off at 50 degrees F outside air.
6. Mixed-Air Control: When the outdoor air enthalpy is lower than the return air enthalpy, the unit will operate in economizer mode as follows: the return, relief and outdoor air dampers will modulate to control the discharge air temperature set point (adjustable) as detected by the discharge air temperature sensor. There will also be a mixed air temperature controller to modulate dampers to maintain minimum mixed air temperature set point. When the unit is not in economizer mode the mixing dampers will modulate to the minimum outdoor air position required to maintain return air CO2 levels as measured at VOC-1 at set point. Dampers will modulate to maintain discharge air temperature with mixed air temperature controller being a low limit controller.
7. Filters: A differential pressure switch DPS-1 installed across the filter will signal an alarm to the BAS when the filter differential pressure exceeds set point.
8. Hydronic Cooling Unit: During occupied periods, when the fan is running the normally, open chilled water valve will be modulated to maintain cooling coil discharge air temperature as measured at set point. When in economizer mode, outside damper will open first,

then the chilled water valve will be modulated to maintain discharge air temperature set point.

a. During shutdown periods, when the fan is off, the cooling coil valve will be closed.
b. During occupied periods, CO2 control shall be considered.

9. Hot Water Reheat Coil Control:

a. During occupied periods, when the fan is running, the reheat coil will be modulated to maintain discharge air temperature at set point as measured at TTE-4. The space temperature sensor will be used to reset the discharge air temperature set point.
b. When the unit is cooling and the return air relative humidity rise above set point, the cooling coil valve will modulate open and the reheat coil valve will modulate to maintain space temperature at set point.
c. During unoccupied periods, when space temperature falls below set point, start fan and modulate reheat coil valve to maintain set point.

C. **Sequence of Operation for 100 percent Outside AHU**

Normal condition

1. Fan off – dampers return to normal positions. Chilled water valve closed (unless preheat temp below 45 then chilled water valve open). Humidity valve closed. Preheat valve will modulate to maintain a preheat set point. (Adj.). Glycol system will maintain a Glycol Water supply temp via a schedule to ensure at startup the unit will not trip freeze stat.

2. The Fan will be started by the DDC (or by manual intervention through SCADA system). Upon a start command the outside air damper will open first. After proof of outside damper open, supply fan and associated exhaust fan will start. AHU will maintain constant discharge air temp of 55 degree (adj.) by using preheat and chilled water valve. If discharge temp is above set point then preheat valve modulated closed and modulate chilled water valve open. If discharge below set point then modulate chilled water valve closed and then modulate preheat valve open. Preheat valve will also be modulated to maintain a minimum Preheat set point (adj.)

3. Exhaust fan-off - position isolation and smoke dampers closed. Upon rotation of fan the dampers will open.

4. Supply fan will start at minimum speed (if the system is variable volume). Supply fan will ramp up and down to maintain a static pressure to a set point. (Adj.).

5. Exhaust fan on startup will ramp up to maintain a static pressure set point (Adj.) (if the system is variable volume).

6. Humidity control using the humidity sensor will modulate Humidity valve to maintain a space humidity set point (note: no return RH in a 100% OA system. Recommend to control discharge RH set point and reset discharge RH from space RH sensor) (adj.) and use discharge humidity as a high limit cut off (separate high-limit set point on the same sensor).

7. Smoke detectors will stop the supply and reduce the exhaust fan operation to maintaining building safety.

D. **Sequence of Operation for Radiation System**

1. Radiation pumps shall start when outside air temp below **55 Degrees** (adj.). Upon proof of flow the steam valve or mixing valve will modulate open to maintain a water temp determined by a Schedule as follows; at 60 degree outdoor air temperature, heating water temperature = 100 degrees (adj.) and at 0 degree outdoor air temperature, heating water temperature = 180 degrees (adj.)

2. When outside air temp is above 60 degree (adj.) the pump shall be stopped and steam valve closed.

3. Differential pressure transmitter will control variable frequency drive to maintain a pressure set point (adj.).

E. **Sequence of Operation for Reheat System**

1. Reheat pump shall run continuously. When reheat supply temp is below set point and there is proof of flow then the steam valve shall modulate open to maintain a 180 degree (adj.) set point.

2. Differential pressure transmitter will control variable frequency drive to maintain a pressure set point (adj.).

F. **Sequence of Operation for Chilled Water System**

1. **Return chilled water** - The choke valve will modulate closed when the differential temperature between the primary supply and secondary return water temp is less than set point (adj.).
2. The CHW choke valve will modulate open when the differential temperature between primary supply temp and secondary return temp is greater then set point (adj.)

3. The CHW choke valve will be modulated open to maintain a maximum return water temperature, overriding the other controls to maintain a chilled water differential of 10 degrees F (adj.).

4. CHW choke valve will modulate close when the building (_P) is over 18 PSIG (adj.).

G. **Sequence of Operation for Chilled Water Pump**

Chilled water pump will be started and stopped via operator command. Pump will start at minimum speed and via a differential pressure sensor vary pump speed to maintain a secondary CHW differential pressure set point (adj.).

H. **Sequence of Operation for VAV Systems**

On a fall in space temperature, space temperature sensor operating through DDC controller will modulate closed the air volume damper to minimum position then modulate open the reheat valve. Maintaining a temperature space set point.

On a rise in space temp the reverse of the above should occur.

16.0 PROJECT CLOSEOUT REQUIREMENTS

A. Before control and monitoring systems are closed out a point-to-point verification, from the field devices to OCC must take place. The system controls should be tested at each unit level, AHU, VAV box, Hydraulic system, etc. Components failed and replaced during the warranty period must repeat point to point check out.

B. There will be a verification test of blackout startup of the system. Also operation under abnormal conditions, as emergency power, etc.

C. The contractor shall submit three binders and electronic copies for each project including the following:

1. P&ID diagram for each system.

2. Point listing, by system, with variable acronym, software address, point type, and engineering units.
3. Logic step diagram system.
4. Wiring diagrams by system including termination nomenclature, location and wiring identification.
5. Calibration sheet (minimum 3-point calibration) for each device identified in the design as requiring calibration certificate, indicating calibration date and model number. Include equipment calibration certifications for calibration standards.
6. Final tune-up list of parameters for each PID loops, including a time graph showing response to a disturbance of a 15%.
7. All software, hardware and licenses necessary to operate, maintain, update modify the system. Including a final version of the software operating the building.

D. Confirmation in writing by the controls contractor that:
1. All construction Requests for Information (RFIs) are resolved.
2. All shop drawings, as built and submittals are completed.
3. All required training is completed.
4. All Testing, Adjusting and Balancing and commissioning activities are completed-Refer to Selections 15010 and 15990.

END OF SECTION