SECTION 23 09 93
SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.1 STIPULATIONS

A. The specifications sections "General Conditions to the Construction Contract", "Special Conditions" and "Division 01 - General Requirements" form a part of this Section by this reference thereto, and shall have the same force and effect as if printed herewith in full.

1.2 ADDITIONAL RELATED DOCUMENTS

A. Division 23 Section "Instrumentation and Control for HVAC" for control equipment and devices, system performance, commissioning, and submittal requirements.

B. Other Division 23 Sections for factory mounted controls and communication interface gateways and DDC System Sub-Contractor led commissioning for equipment with factory controls packages.

C. Division 26 for VFDs with communication interface gateways.

1.3 SUMMARY

A. This Section includes control sequences for HVAC systems, subsystems, and equipment.

B. Throughout this specification, any reference to "DDC Contractor", "ATC Contractor or Subcontractor", "BMS Contractor", "BAS Contractor", "Control Contractor", "installer", "supplier", "Manufacturer" or "local field office" shall be interpreted as referring to the automatic temperature control system supplier/installer performing the work of Division 23 Section "Instrumentation and Control for HVAC".

C. Where the term 'workstation' is used, it shall mean all means of human-machine interface with the DDC system.

D. Refer to the Drawings for locations of some control devices, and for quantities of equipment and systems.

1.4 QUALITY ASSURANCE

A. Code Compliance: All HVAC controls shall be programmed in order to meet all requirements articulated in ASHRAE 90.1-2016 and the 2018 International Energy Conservation Code.

B. ASHRAE Guideline 36: Comply with the latest version of the guideline and all current addendums to the greatest extent possible. Identify any discrepancies between the sequences of operation included with these contract documents and the Guideline. Resolve discrepancies by requesting clarification from the Architect / Engineer.

C. Site Specific Application Programming and Qualifying Programming Experience: The programming shall meet the functional intent of the sequences of operation included in the contract documents. These sequences are intended to be performance based. Implementations that provide the same functional result using different underlying detailed logic will be acceptable. It is not acceptable for the BAS Contractor to merely provide typical or 'canned' software programs without thorough comparison to the contract document sequences of operation, and resulting modification as required. While the BAS Contractor is encouraged to utilize control programming that has been thoroughly tested and successfully implemented on past projects, where the control applications are very similar to this project, the BAS Contractor is still obligated to make project specific modifications as required, and to identify discrepancies between the Contractor's proposed sequence and those in the contract documents. Similarly, the BAS Contractor shall evaluate the suitability of the contract document sequences of operation for implementation on this project. It is the BAS Contractor's responsibility to request clarification on sequence issues and questions that require such clarification, and to request approval for deviations from the contract document sequences of operation. All site specific programming shall be fully documented and submitted for review and approval, both prior to downloading into the panel, at the completion of functional performance testing, and at the end of the warranty period.

1.5 GENERAL SEQUENCE OF OPERATION REQUIREMENTS

A. Refer to the Article titled "General System Requirements" in Division 23 Section "Instrumentation and Control for HVAC" for additional, general system requirements

B. Scope: All control functions described in the sequences of operation shall be performed by the DDC system unless explicitly indicated otherwise. All work described shall be provided by the ATC system supplier/sub-contractor under the automatic temperature controls specification section unless explicitly indicated otherwise.

1. In addition to meeting the requirements of the specifications, the DDC system sub-contractor is required to provide a particular control point if that control point is indicated in any one of the three possible control work representations that are part of these contract drawings. These three representations are the entirety of the HVAC drawings, the control sequences of operation, and the control diagrams on the HVAC drawings (when a diagram has been prepared for a given system or type of equipment)**.** The omission of a particular control point from one or more of these three representations shall not be construed to mean this particular control point is not required if it is indicated in one of these representations. Inclusion of the point in any one of the representations obligates the Contractor to provide the point as part of the complete and functional control system.

C. System Graphics: For each system or each piece of controlled equipment, display all points described in the sequences of operation or indicated in a control diagram on the Drawings (when applicable)**,** as well as all operating modes, setpoints, high limit settings, time out periods, run times, temperature and pressure reset schedules, and active alarm conditions. Graphics of equipment and systems shall reflect the 'as-built' condition (i.e. do not use generic graphics). Locate all instruments and control objects as actually installed in the completed building. The graphics shall be no less detailed than the control diagram on the Drawings (where a diagram has been prepared for given system or type of equipment).

1. Hardwired Points: System graphics shall display all system points associated with physical / hard-wired input and output devices (e.g. temperature and pressure sensors, safety switches, valves, dampers, points to VFDs and magnetic motor starters, etc.)
2. Gateway Interfaces: System graphics shall incorporate all 'communication' points available through integration gateways provided with packaged equipment controls, air and water flow meters, and other devices provided with such communications gateways. Extend the appropriate / required portion of the DDC system network and connect to all such

gateways. All gateway communication points shall be displayed on the system graphics on a separate page, linked from the main system graphic that shows all hard wired points. Communication points selected by the Architect / Engineer or the Client Agency shall also be displayed on the main system graphic.

3. Additional Specific Requirements:

    a. Dampers and Valves: Clearly identify the commanded position of each actuator position as % open or % closed. Actuator feedback shall be shown on the graphic, included the status of related end switches.
    b. Air Handling Units and DOAS Units:

        1) Display the current outdoor temperature and humidity conditions.
        2) Clearly identify and provide navigation links to the graphics of all equipment or systems serving utilities to the air system.
        3) Display the current value and current control setpoint of all utilities served to the air system. Use the closest upstream sensor if a local sensor is not in the scope of work.
        4) Display the current operating mode of the air system. (e.g. Heating, Cooling, Warm-up, Economizer, etc.)
        5) Show all process variables and setpoints related to the discharge of the air system (pressures, flow rates, temperatures, humidity, dewpoint, etc.)
        6) Display current CO2 values and control setpoints, as applicable.

D. Adjustable Values: All setpoints, thresholds, differentials, time delays, reset schedules, etc. indicated in the sequences of operation are initial recommendations only and shall be adjustable by the building operator at the DDC workstation or web browser via system graphics without re-programming (i.e. no alteration of system program code shall be required), assuming the user has the required access level.

1. All adjustable values shall be determined and/or verified during the DDC system commissioning process performed by the DDC system sub-contractor.
2. Software points shall be used for all such adjustable values. Fixed scalar numbers shall not be embedded in programs except for physical constants and conversion factors.

E. Units: All temperatures indicated in the sequences are in degrees Fahrenheit (deg. F.). Units of air pressure are in inches water gauge (in. w.g.)

F. Damper and Valve Fail Positions: Unless explicitly specified otherwise elsewhere, all damper and valve actuators shall have spring return mechanisms (except where explicitly noted otherwise, and for 8" valves and larger, which do not require spring return). Unless explicitly indicated otherwise in the sequence of operation or on the Drawings, dampers and valves shall be configured for the following spring return fail positions.

1. Outdoor air damper - Fail closed
2. Relief air damper - Fail closed
3. Return air damper - Fail open
4. Exhaust fan dampers - Fail closed
5. Face and bypass dampers - Fail open to face, closed to bypass
6. Equipment automatic isolation valves - Fail open
7. Hot water and Steam 2-way control valves for temperature control:

    a. Air handling units and IFB coils - Fail open
    b. Convectors, radiant panels, fin tube radiators, and similar space heaters - Fail open
    c. Heat exchangers - Fail closed

8. Hot water 3-way control valves for temperature control:

    a. Air handling units - Fail open to coil flow
    b. Convectors, radiant panels, fin tube radiators, and similar space heaters - Fail open to unit flow.

9. Note: The normal (e.g. spring return or fail) position of 3-way mixing and diverting valves shall be as described in the sequences of operation or as noted on the Drawings. The graphical representation on details and flow diagrams shall not be construed to indicate otherwise. Mixing and diverting valves hall be piped to produce the normal position described or noted.

G. End Switches: End switches, where required by the sequences of operation, shall be a device that verifies the physical position of the damper. The use of auxiliary contacts on the actuator to indicate position is not acceptable. End switches shall be used to provide a "digital (binary) input" to the DDC system.

1. In addition to those indicated in the Sequences of Operation, provide an end switch to confirm the fully closed status of all dampers at intake and relief /exhaust louvers, gravity ventilators, and similar locations where the damper maintains continuity of the exterior building envelope when the associated air handling apparatus is de-energized or the damper is commanded closed. The DDC system shall issue an alarm when the damper fails to fully close.

H. Damper and Valve Positions: Knowledge of damper and valve position are required for implementation of trim-and-respond type reset control loops, such as variable speed pump and fan remove differential pressure setpoint reset control. The following are acceptable methods for determining valve and damper positions:

1. Analog / Proportioning Actuators: Valve or damper position may be assumed to be equal to analog signal to actuator.
2. Floating Actuators: Provide either a separate position feedback analog input control point, or alternatively, the position may be estimated by timing pulse-open and pulse-closed commands if combined with an auto-zeroing function whenever the damper or valve has been driven full closed. The second option is not acceptable for 24/7 systems / applications that lack an unoccupied mode of operation, unless a forced/override auto-zero is implemented at least once every 48 hours.
3. Two-Position Actuators: Such valves may be ignored for the purposes of such control loop functions.

I. Temperature Alarms: If space temperatures that are monitored through the DDC system fall more than the adjustable alarm levels, the DDC system shall issue an alarm. Recommended alarm settings:

1. High limit for occupied spaces: 84 deg. F.
2. High limit for data rooms: 80 deg. F.
3. High limit for other unoccupied spaces: 104 deg. F.
4. Low limit for occupied spaces: 58 deg. F.
5. Low limit for unoccupied spaces: 52 deg. F.

J. Status Monitoring of Motor Driven Equipment: All pump and fan status monitoring shall be achieved through current switches that have an adjustable trip point. Adjust so that setpoint is below minimum operating current and above motor no-load current.

K. Run Time Totalization: The DDC system shall provide a run-time totalization feature for all fans, fan-containing equipment, pumps, refrigerant compressors, and all other HVAC equipment controlled by the DDC system except as noted otherwise.

1. Exception: Run-time totalization is not required for cabinet unit heaters, horizontal unit heaters, and for any equipment not being controlled or monitored by the DDC system.

L. Freezestats: Freezestats shall be installed in a uniform, horizontal serpentine pattern and in a downward direction from the body of the device. Element shall be exposed to all areas that encounter low temperature, including along the bottom of the coil(s), from end to end. Provide 1 foot of sensing element for each square foot of coil area. Provide as many freezestats as required for full coverage.

M. Safety Device Wiring: Unless explicitly noted otherwise, all safety switches/devices (e.g. freezestats, duct pressure limit switches, vibration switches, water overflow sensors, smoke detectors, and similar devices performing a life safety function or serving to prevent damage to systems and materials) shall be of the manual reset type, and hardwired to the appropriate motor controller(s) for fan shut down circuit, and/or valve/damper actuator power sources, as prescribed by the sequence of operations. Control power relays and associated wiring shall be provided for automatic/power fail positioning of dampers and actors via spring return actuators. Manual reset type safety devices shall also provide a binary input (BI) to the DDC system for informational / alarming purposes. Unless explicitly indicated otherwise, provide the following sequence of operations through hardwiring (i.e. not via a DDC system controller and programming). Upon activation of the safety device, the following shall occur, and shall remain as such until the alarm condition is cleared at the device:

1. Smoke Detection Shutdown: All associated air system fans (e.g. supply, return, relief, exhaust, etc.) shall be de-energized.
2. Freezestats: All associated air system fans (e.g. supply, return, relief, exhaust, etc.) shall be de-energized, the steam and/or hydronic valve(s) providing heating shall be fully opened, the chilled water valves shall be fully opened, the return damper shall be fully open, and the outdoor air, relief, and exhaust dampers shall be fully closed.
3. High Duct Static Pressure Switches: All associated air system fans (e.g. supply, return, relief, exhaust, etc.) shall be de-energized.
4. AC Condensate Drain Pan High Water Sensors: The associated chilled water valve shall be fully closed, or the cooling refrigeration circuit operation shall be disabled, as applicable.
5. AC Condensate Pump High Water Sensors: The associated chilled water valve shall be fully closed, or the cooling refrigeration circuit operation shall be disabled, as applicable.
6. High Temperature Limit on Heat Exchangers: The steam or hydronic valve(s) providing the source of energy shall be fully closed.

N. Air System Maintenance Start-Stop Switches: A maintenance shutdown / start-up switch shall be provided for each AHU and DOAS unit. Locate this switch near to the supply fan motor controller or disconnect switch. The switch shall provide a pair of binary inputs to the DDC system. Whenever the switch is positioned to 'off', the entire air system shall de-energized via software in the manner identical to the manual system shutdown command initiated through the DDC system interface. The 'on' position / input shall re-start the system in accordance with programming.

1. Provide labeling on the supply fan motor controllers and disconnect switches referring staff to the maintenance switches for unit shutdown PRIOR to disconnecting power at service disconnect (safety) switches in order to prevent control system alarms.
2. Provide labeling on the maintenance switches indicating that these switches are for control system software shutdown of the unit only, and that motor controllers / disconnect switches must be locked and tagged prior to working on the unit.

O. Cascade Loops: Cascade loop methods of control over modulating (analog) output devices (e.g. variable speed supply fans, steam and hydronic control valves, etc.) shall be utilized wherever required to produce stable control while providing quick response required to prevent problematic operating conditions or safety shutdowns.

1. Example: Heating coil control valves shall be directly piloted from an averaging temperature sensor located immediately downstream of the coil, with the setpoint of that "local" control loop reset as required to provide the desired unit supply air temperature to the spaces, as measured by a temperature sensor in the main supply air duct connected to the air handling unit. The local HW valve control loop shall be quick reacting, with the reset loop slower reacting. By this method, the heating coil can produce proper temperature air quickly in response to rapid changes in upstream variables to prevent freezestat trips or frozen coils, but without the risk of HW valve hunting and other instabilities due to system inertia between the heating coil and the main AHU supply air temperature sensor.

P. Duct and Plenum Air Temperature Sensor Applications: Use averaging type temperature sensors in ductwork greater than 48" in any dimension, where air temperature stratification exists (such as a mixed air plenum), immediately downstream of an air blender, and immediately downstream of any heat exchanging element (coil, furnace, energy recovery heat exchanger, etc.).

Q. Dead-bands: Control loops shall incorporate dead-bands of an appropriate range in order to prevent 'hunting' or excessive 'cycling' of the output device (e.g. variable speed fan controlled to remote duct static pressure, space temperature sensor controlling an on-off exhaust fan, etc.), except as specifically indicated otherwise. Dead-band ranges shall be adjustable, with proposed initial settings indicated on the ATC primary submittal.

R. Optimal Start Warm-Up and Cool-Down Modes: Air handling units and similar air systems with time of day schedules (i.e. not continuous operation) shall incorporate warm up and cool down cycles. The units shall be operated in advance of an occupancy period, with a minimum outdoor airflow rate of zero (0) cfm. The duration of this warm up / cool down period shall be auto-adaptive and dependent on the outdoor air temperature and at least one representative space temperature input signal.

S. Airflow Measurement of Fan Arrays: The DDC system shall monitor the airflow rate of each individual fan in the array, and shall sum the airflow values from all operating fans to determine the total airflow rate of the array.

1.6 OUTDOOR AIR CONDITIONS MONITORING

A. The DDC system may utilize a global outdoor air temperature and relative humidity sensors for the project in lieu of measuring outdoor air conditions individually for each sub-system requiring outdoor air condition(s) input value(s). The DDC system shall calculate the outdoor air enthalpy, dew point, and wet bulb from the measured dry bulb and percent relative humidity values. Reuse of existing points is also acceptable. Install sensors on an exterior wall with a North exposure and with a weather shield. Do not locate near exhaust or relief air discharges (min. 20 foot separation), or above doors or operable windows.

B. These values shall be transmitted to the local controller for, and be displayed on the workstation system graphics of, any air system that draws in outdoor air or uses outdoor air as a control parameter, the chilled water system, and the heating hot water system.

1.7 STEAM SYSTEM MONITORING

A. Steam Pressure Monitoring: The DDC system shall monitor the presence of incoming campus steam service by way of a clamp-on temperature sensor.

B. Condensate Pump Receiver Level Monitoring: The DDC system shall monitor the high limit level in the steam condensate pump receiver, and shall issue an alarm if the high limit level is reached. The DDC system shall monitor the operating status of each condensate pump on the pump-receiver set.

1.8 HEATING HOT WATER SYSTEM WITH STEAM TO WATER HEAT EXCHANGERS

A. System Description: The system primarily consists of variable speed hot water pumps HWP-1 and HWP-2, and two steam to water heat exchangers HX-1and HX-2. The heating source is campus steam.

B. Overall System Start/Stop: The system shall be manually enabled or disabled by the building operator by command at the DDC system operator's workstation or automatically as described below, with the mode selected through the workstation graphic for the system. When the system is de-energized, the pumps shall be de-energized and the heat exchanger campus steam control valve(s) shall be fully closed.

1. The hot water system shall also have a selectable automatic start/stop mode based on outdoor air temperature. The hot water system shall be enabled and operate continuously upon a fall in outdoor air temperature below 62 deg. F. for longer than 1 hour, assuming steam is available, as determined by sensed campus steam pressure. On a rise in outdoor air temperature above 65 deg. F. for longer than 1 hour, or when steam is not available, the system shall be completely de-energized.

C. Heating Hot Water Supply Temperature Setpoint Outdoor Air Reset Schedule: The DDC system shall provide a variable HWS temperature setpoint in accordance with the following reset schedule (i.e. the setpoint temperature shall vary continuously between the two values indicated):

1.

Outdoor Air Temp. (Deg. F)	Secondary HWS Temp. (Deg. F.)
10	180
60	140

2. The minimum HWS temperature shall be 140 deg. F., and the maximum shall be 180 deg. F.
3. All reset schedule limits shall be adjustable from the workstation graphics.

D. Hot Water Pumps (HWP-1 and HWP-2) Control: The DDC system shall monitor the status of the pumps and shall have start/stop control over the pumps. The DDC system shall issue an alarm whenever a pump fails to run. The pump set shall operate in a duty-standby fashion. If the duty pump fails to operate, the standby pump shall be energized. The DDC system shall log the run time of each pump separately, and every 14 days the DDC system shall select the duty pump as the pump with the least amount of run time. During change-over events, the new duty pump shall be energized prior to de-energizing the old duty pump so as to minimize any interruption to building heating or flow to the HXs.

E. Steam to Water Hot Water Heat Exchangers (HX-1 and HX-2) Control: The heat exchangers shall operate in a duty-standby fashion, with the switchover being performed automatically. Whenever a hot water pump (HWP-1 or HWP-2) is energized, the DDC system shall enable the duty heat exchanger. When a heat exchanger is enabled, the DDC system shall fully open the

associated load side isolation valve. The DDC system shall monitor the load side HWS temperature leaving each heat exchangers and shall modulate the steam control valves on the associated heat exchanger to maintain heat exchanger discharge temperatures equal to the desired hot water system supply temperature. When a heat exchanger is disabled while the system as a whole is operating, the associated steam control valves and water isolation valve shall remain fully closed.

1. Modulating Steam Valve Set Sequencing Control: On an initial call for heat, the 1/3rd control valve shall modulate as required to maintain supply water temperature at setpoint. Once the 1/3rd valve has become 95% open, upon a continued fall in supply water temperature, the 2/3rd valve shall modulate open to maintain setpoint as the 1/3rd valve modulates closed at a fixed rate. The rate of closure of the 1/3rd valve shall be slower than the speed or response of the 2/3rds valve to limit the disruption to the hot water supply temperature. Once the 2/3rds valve is 95% open, on a further fall in supply water temperature, the 1/3rd valve shall modulate open to maintain supply water temperature at setpoint. On a rise in supply water temperature, the reverse shall occur. When the 2/3rds valve is operating by itself and the valve has reached 10% open, on a further rise in supply water temperature, the 1/3rd valve shall modulate open to maintain setpoint as the 2/3rds valve closes at a fixed rate. The rate of closure of the 2/3rds valve shall be slower than the speed or response of the 1/3rds valve to limit the disruption to the hot water supply temperature.
2. Flow Monitoring and Safeties: The steam control valves of a particular heat exchanger shall fully close when flow is not detected through the heat exchanger. A redundant temperature sensor located in the load-side supply water leaving each heat exchanger shall be used to enable a high limit control loop that shall override the signal to the modulating control valves to prevent the supply water temperature leaving the heat exchanger from rising above 190 deg. F. should the primary temperature control loop fail.

    a. Flow Alarms: Whenever a the hot water system is enabled and no flow is detected at either heat exchanger, an alarm shall be issued. Whenever the hot water system is disabled and flow is detected at either heat exchanger, an alarm shall be issued. Whenever a heat exchanger is enabled and no flow is detected, an alarm shall be issued. Whenever a heat exchanger is disabled and flow is detected, an alarm shall be issued.
    b. Heat Exchanger Failure: If a heat exchanger fails to operate (no load side flow detected or the discharge temperature is more than 10 deg. F. below setpoint for longer than 10 minutes), an alarm shall be issued and the standby heat exchanger shall be enabled (if not already enabled).
    c. High Temperature: Whenever the discharge temperature of a heat exchanger is more than 10 deg. F. above setpoint for longer than 10 minutes, an alarm shall be issued. Whenever both heat exchangers are operating and the discharge temperature of one of the heat exchangers is more than 10 deg. F. above setpoint for longer than 10 minutes, the source side modulating control valve of the other heat exchanger shall be controlled to maintain the overall system supply water temperature at setpoint.

3. Duty-Standby Rotation: The DDC system shall log the operating time of each heat exchanger separately, and every 14 days the DDC system shall select the lead heat exchanger as the heat exchanger with the least amount of operating time. During change-over events, if only one heat exchanger is operating at that time, the valves (both load side and source side) of the new lead heat exchanger shall open simultaneously as the old lead heat exchanger valves closed so as to minimize any interruption to building heating.
4. Whenever the hot water system is disabled and both HWP-1 and HWP-2 are de-energized, the hot water heat exchanger isolation valves shall be fully open. The isolation valves shall be spring return, normally open.

5. Whenever both HWP-1 and HWP-2 are de-energized, the modulating steam control valves shall be fully closed. Steam control valves shall be spring return, normally closed.

F. Miscellaneous System Monitoring:

1. Temperatures: The DDC system shall monitor the temperature of the HWS piping to the building, the HWR piping combing back from the loads. Refer to the Drawings for other temperature monitoring points. The DDC system shall issue an alarm whenever the HWS temperature to the loads falls or rises more than 10 degrees beyond the desired temperature for longer than 10 minutes.
2. Air/Dirt Separator: On a rise in pressure drop across the air/dirt separator above the high limit level, the DDC system shall issue an alarm.
3. Bypass Filter: On a rise in pressure drop across the filter above the high limit level, the DDC system shall issue an alarm.
4. Make Up Monitoring: Whenever the flow switch detects a make-up water flow exceeding 0.5 gpm for longer than 5 minutes, an alarm shall be issued by the DDC system.

1.9 DEDICATED OUTDOOR AIR SYSTEMS AND INTEGRAL FACE AND BYPASS COILS

A. This sequence applies to the DOAS-1 / IFB-2 system and the DOAS-2 / IFB-2 system.

B. System Start/Stop Control and Mode Control: A maintenance shutdown / start-up switch shall be provided for the DOAS unit. Locate this switch near the unit / supply fan disconnect switch. The switch shall provide a pair of binary inputs to the DDC system. Whenever the switch is positioned to 'off', the entire air system shall de-energized via software in the manner identical to the manual system shutdown command initiated through the DDC system interface. The 'on' position / input shall re-start the system in accordance with programming. Provide labeling on the supply fan disconnect switch referring staff to the maintenance switches for unit shutdown PRIOR to disconnecting power at service disconnect (safety) switch.

1. Whenever the DOAS unit supply fan is de-energized:

a. The following also be de-energized:

1) Exhaust fan(s) serving the same portion of the building.
2) Associated condensing unit
3) Electric re-heat coil.

b. The outdoor air damper shall be fully closed.
c. Whenever the DOAS unit is de-energized and the outdoor air temperature is below 42 deg. F., the IFB pre-heat coil control valve shall continue to modulate to maintain a temperature at the heating coil discharge air sensor equal to 55 deg. F. Whenever the unit is de-energized and the outdoor air temperature is above 42 deg. F., the pre-heat hot water coil control valve shall be fully closed.

2. Occupied / Unoccupied Fan Control: Whenever the system is called to run, the supply fans shall not be energized until the outdoor air damper is verified fully open via end switch. When the supply fans begin to operate, the hot water control valve, IFB damper, electric reheat coil, condensing unit shall all come under automatic control as described further in this Sequence.

a. The DOAS supply fan shall operate continuously when the system is in the occupied mode.

3. Unoccupied Mode: The unit shall remain de-energized.

C. Air Cooled Condensing Unit Control:

1. Compressors: The DDC system shall have start/stop control over each constant speed compressor, and shall have start/stop and speed control over each variable speed compressor. The DDC system shall monitor the operating status of each compressor and shall issue an alarm if a compressor fails to operate as commanded.
2. Condenser Fan(s): The condenser fan shall be controlled by the packaged refrigerant pressure controls on the condensing unit.
3. Control Coordination with Manufacturer: The DDC system sub-contractor shall review the complete proposed control programming with the unit manufacturer's representative to ensure stable and safe operation of the unit, and to comply with the manufacturer's recommendations and equipment warranty requirements. The DDC system shall incorporate a control differentials about the setpoints to prevent rapid cycling of compressors. The sequence of staging of the compressors shall reflect the size and quantity of compressors available in the supplied unit to provide for the best possible matching of unit capacity to load.

D. Electric Reheat Coil Control: The packaged electric coil SCR controls shall directly control the heating output. The DDC system shall provide an analog output to the coil power and control panel. The DDC system shall also provide a binary output for enable / disable control of the heater, and shall receive a binary input from the coil controller for a coil fault alarm.

E. Integral Face and Bypass (IFB) Heating Coil Output Control: The heating output of the IFB coil shall be controlled through the integral face and bypass dampers and the flow of hot water to maintain the desired pre-heating coil discharge air temperature.

1. When the outdoor air temperature is above 42 deg. F., the face and bypass damper shall be positioned for full coil air flow and the hot water control valve shall modulate as required to maintain the desired heating coil discharge air temperature.
2. Whenever the outdoor air temperature is below 42 deg. F., the hot water control valve shall be fully opened, and the face and bypass dampers shall be modulated to vary the coil heating output. Once the bypass dampers are set for full airflow bypass, upon a continued excess of heating output, the hot water control valve shall be modulated closed. The hot water control valve shall have a minimum position of 10% open to coil flow when under this operating condition.

F. Supply Air Temperature Setpoint Control: The system supply air dry bulb temperature shall be maintained at setpoint by modulating the air cooled condensing unit's compressor speed, IFB pre-heating coil heating output, and the re-heat coil output in sequence.

1. On a rise in supply air temperature, the heating output of the electric re-heat coil shall be reduced first, and once fully de-energized, then the IFB pre-heat coil heating output shall be reduced (i.e. the IFB pre-heat coil is the first stage of heating, and the electric reheat coil is the second). On a continued rise in in supply air temperature, the DDC system shall enable the condensing unit and shall modulate/stage the cooling capacity to maintain the desired supply air temperature.
2. Cascade Loops: All coils shall be controlled through a cascade loop, whereby the coil is directly piloted from averaging temperature sensor located immediately downstream of the coil, with the setpoint of that "local" control loop reset as required to provide the desired unit supply air temperature. The local loops shall be quicker reacting, with the reset loop slower reacting. The system supply air temperature sensor resetting the local control loops shall be located downstream of all system fans and heat exchange or humidification components.
3. The supply air dry bulb temperature setpoint shall be reset by the DDC system in accordance with the following reset schedule (i.e. the setpoint temperature shall vary continuously between the two values indicated):

a. Outdoor Air Temp. (Deg. F) Supply Air Temp. (Deg. F.)

80 ---------- 62
60 ---------- 72

b. The minimum supply air temperature setpoint shall be 62 deg. F., and the maximum shall be 72 deg. F.
c. All reset schedule limits shall be adjustable from the workstation graphics.

G. Supply Air Maximum Dewpoint Control Mode: The DDC system shall monitor the supply air temperature and relative humidity, and shall calculate the supply air dewpoint. On a rise in supply air dewpoint above the maximum value of 53 deg. F., the above described dry bulb temperature control of the cooling coil shall be overridden, and the cooling coil capacity shall be modulated, through control of the condensing unit compressors, to maintain the desired maximum supply air dewpoint temperature at setpoint.

1. In this mode, the unit dry bulb supply air temperature shall be maintained at setpoint by modulating the output of the electric reheat coil.

H. Miscellaneous Monitoring and Safeties:

1. Fan Proof Alarm: The DDC system shall monitor the supply fan status and shall issue an alarm if the fan fails to operate.
2. Damper Monitoring: The fully closed and fully open statues of the outdoor air damper shall be monitored. The DDC system shall issue an alarm any time the damper does not fully close or fully open as commanded.
3. Air Temperature and Relative Humidity Monitoring: The DDC system shall monitor the temperature and relative humidity in locations indicated on the control diagram on the Drawings.
4. Filters: Filter pressure drop shall be monitored by the DDC system at the filter bank associated with the IFB coil. The DDC system shall issue a maintenance alarm whenever any particular filter bank's pressure drop exceeds its high limit setpoint.
5. Freeze Protection: A freezestat shall be provided downstream of the IFB pre-heating coil. Locate the sensor approximately 3 feet downstream of the coil, in accordance with the coil manufacturer's recommendations. Whenever the temperature at any individual 1 (one) foot long section of the freezestat falls to 38 deg. F., the DDC system shall de-energize the supply fan, fully open the IFB hot water coil control valve to coil flow, and fully close the outdoor air damper, and shall issue an alarm at the operators workstation, along with the reason for the shutdown..

    a. Utilize hardwiring to effect fan, valve, and damper responses.

6. Static Pressure Safety: Whenever the suction pressure of the supply fan(s) as measured on the suction side of the fan exceeds negative 2.0" w.g., the supply fan shall be de-energized and an alarm issued at the operator's workstation, along with the reason for the shutdown.

    a. Utilize hardwiring for fan shutdown response.

7. AC Condensate Drain Pan Overflow: The DDC system shall monitor the overflow condition of the AC condensate drain pan, and if condensate reaches the high limit level, the DDC system shall de-energize the condensing unit and shall issue an alarm, along with the reason for the shutdown.

    a. Utilize hardwiring for condensing unit lockout response.

1.10 TYPICAL EXHAUST FAN CONTROLS

A. This sequence applies to all exhaust fans except EF-7 serving the hot water mechanical room.

B. The DDC system shall have start /stop control over the fan and shall monitor fan status of the fan. The DDC system shall issue an alarm if the fan fails to operate. The fan(s) shall normally operate continuously whenever the associated DOAS unit is also operating. Whenever the associated DOAS unit is de-energized, the exhaust fans shall be de-energized.

1. When the fan is called to run, the motorized exhaust damper shall be fully opened, and when confirmed open via end switch, the fan motor shall be energized. When the fan is de-energized, the damper shall be fully closed. The damper shall be normally closed, spring return. The DDC system shall issue an alarm if the damper fails to fully open.

    a. The DDC system shall also monitor the fully closed position of the damper, and shall issue an alarm if the damper fails to fully close.

C. EF-DOAS Unit Associations:

1. DOAS-1: EF-2
2. DOAS-2: EF-1, 3, 4, 5, and 6.

1.11 EF-7 CONTROL

A. The DDC system shall have start /stop control over the fan and shall monitor fan status of the fan. The DDC system shall issue an alarm if the fan fails to operate. The DDC system shall monitor the space temperature. On a rise in space temperature, the fan shall be energized and the motorized exhaust and OA intake dampers shall be fully opened. On a fall in space temperature, the fan shall be de-energized, and the dampers shall fully close. The fan shall not be energized on a rise in space temperature if the outdoor air temperature is the same as or greater than the room temperature setpoint.

1. When the fan is called to run, the motorized exhaust and OA intake damper shall be fully opened, and when the exhaust and OA intake dampers are confirmed open via end switch, the fan motor shall be energized. When the fan is de-energized, the dampers shall be fully closed. The dampers shall be normally closed, spring return. The DDC system shall issue an alarm if a damper fails to fully open.

    a. The DDC system shall also monitor the fully closed position of the dampers, and shall issue an alarm if a damper fails to fully close.

1.12 TEMPERATURE CONTROL ZONE OCCUPANCY MONITORING

A. This sequence applies to the Rec Room, Reward Room, all Offices, and the Time Out room, and the Split Systems (SS-x) and Air Handling Units (AHU-x) that serve them.

B. The DDC system shall receive space occupancy signal for selected spaces from the occupancy sensors provided by the Electrical Contractor for control of lighting.

1. The DDC system shall monitor the occupancy sensing status of each occupancy sensor in each monitored space by way of a second set of dry contacts on the sensor(s), or by way of a similar set of contacts on the power pack(s). Coordinate with the .4 Contractor.

C. For SS and AHU temperature control zones that are specified to have occupancy sensor based occupied / unoccupied mode control, the DDC system shall establish separate heating and cooling temperature setpoints for room occupied and room unoccupied modes. In addition, separate setpoints shall be established for the room unoccupied mode based on time of day. The recommended setpoint schedule for occupancy sensor controlled SS and AHU zones is as follows:

1. Room Occupied (regardless of time of day): Design values (DV); 74 deg. F. cooling and 72 deg. F. heating is recommended.
2. Room Unoccupied / During Typical Scheduled Hours of Use / Potential Use: DV+2 cooling (i.e. cooling setpoint shall be two degrees higher than the normal occupied mode value); DV-2 heating (i.e. the heating setpoint shall be two degrees lower than the normal occupied mode value).
3. Room Unoccupied / Outside of Typical Scheduled Hours of Use / Potential Use: DV+6 cooling; DV-10 heating.

D. Where more than one room that is being monitored for occupancy is associated with a given AHU temperature control zone, the DDC system shall consider the zone occupied if any one (1) room is occupied as detected by the occupancy sensors, and the AHU shall operate in the occupied mode. If all rooms associated with a given AHU zone are unoccupied, then the zone shall be considered unoccupied, and the AHU shall operate in the unoccupied mode.

E. DDC system occupancy monitoring and control is required for the following SSs and AHUs and all of the spaces served by those units.

1. SS-1; Supervisor's Office
2. SS-2; Counselor Office #3
3. SS-4; Counselor Office #2
4. SS-5; Counselor Office #1
5. AHU-1; Reward Room
6. AHU-2; Timeout Room
7. AHU-4; Rec Room
8. AHU-8 and AHU-9; Group Therapy

1.13 SINGLE ZONE AIR HANDLING UNITS (AHUs) AND ASSOCIATED AIR COOLED CONDENSING UNITS AND FIN TUBE CONVECTORS

A. System Start/Stop Control and Mode Control: A maintenance shutdown / start-up switch shall be provided for each AHU. Locate this switch near the unit / supply fan disconnect switch. The switch shall provide a pair of binary inputs to the DDC system. Whenever the switch is positioned to ‘off’, the entire air system shall de-energized via software in the manner identical to the manual system shutdown command initiated through the DDC system interface. The ‘on’ position / input shall re-start the system in accordance with programming. Provide labeling on the supply fan disconnect switch referring staff to the maintenance switches for unit shutdown PRIOR to disconnecting power at service disconnect (safety) switch.

B. Occupied and Unoccupied Modes: Space temperature setpoints shall be reset based on time of day schedule. For selected units noted above in the Article titled "Temperature Control Zone Occupancy Monitoring", the setpoints shall also be reset based on occupancy status.

C. Fan Control: The DDC system shall have start/stop control over the unit fan, and shall monitor the status of the fan. The DDC system shall issue an alarm if the fan fails to operate.

1. The unit fans shall operate continuously in both occupied and unoccupied modes.

D. Air Cooled Condensing Unit Control:

1. Compressors: The DDC system shall have start/stop control over each constant speed compressor, and shall have start/stop and speed control over each variable speed compressor. The DDC system shall monitor the operating status of each compressor and shall issue an alarm if a compressor fails to operate as commanded.
2. Condenser Fan(s): The condenser fan shall be controlled by the packaged refrigerant pressure controls on the condensing unit.
3. Control Coordination with Manufacturer: The DDC system sub-contractor shall review the complete proposed control programming with the unit manufacturer's representative to ensure stable and safe operation of the unit, and to comply with the manufacturer's recommendations and equipment warranty requirements. The DDC system shall incorporate a control differentials about the setpoints to prevent rapid cycling of compressors. The sequence of staging of the compressors shall reflect the size and quantity of compressors available in the supplied unit to provide for the best possible matching of unit capacity to load.

E. Space Temperature Monitoring: For the typical AHU, the space temperature shall be monitored in a single location and shall be used to perform the unit temperature control. Exceptions are as follows:

1. AHU-2: The unit shall be controlled by the average heating/cooling demand of the two thermostats. Exception: When the Timeout Room is occupied, only the thermostat in the Timeout Room shall be used to control the unit.
2. AHU-5 and AHU-6 (serving resident bedrooms) shall each be controlled based on their individual return air temperature sensor in lieu of a space temperature sensor. The space temperature sensors indicated on the Drawings for each unit shall be provided only for purposes of local readout of temperature and monitoring / information.
3. Spaces Served By More Than One AHU (applies to AHU-8 and AHU-9): Where more than one AHU temperature control zone is present in a given space, each AHU shall be piloted by its own associated thermostat, however both AHUs serving the same space / area shall have a common heating temperature setpoint and cooling temperature setpoint, so as to prevent different control zones in the space from "fighting" each other. A space temperature setpoint change via the DDC system that is made at either thermostat shall also be automatically applied to the other AHU serving the same space.

F. Temperature Control Sequence:

1. Heating Mode: The condensing unit shall be de-energized, and, on a fall in space temperature below the heating setpoint, the following steps shall be taken, in order:

    a. The AHU hot water coil control valve shall be modulated to produce a supply air temperature as high as 5 deg. F. above space temperature.
    b. The hot water control valves associated with all radiators/convectors serving the same room shall be modulated open in unison, up to 100%. However, the hot water control valves serving the space heater shall be overridden to the fully closed position if the outdoor air temperature rises above 55 deg. F. They shall be re-enabled if the outdoor air temperature falls below 53 deg. F.
    c. The DDC system shall modulate the hot water control valve to maintain the desired heating setpoint, and the maximum heating supply temperature shall be 20 deg. F. above the space temperature.

2. Deadband Mode: When the space temperature is in the dead band (i.e. between the heating and cooling setpoints), the condensing unit shall be de-energized and all heating control valves shall remain fully closed.

3. Cooling Mode: On a rise in space temperature above the cooling setpoint, all hot water control valves (coil and radiators) shall be fully closed and the condensing unit compressors shall be staged /modulated to maintain the space temperature at the cooling setpoint. On a fall in space temperature, the reverse shall occur. A 2 deg. F. space cooling differential centered about the cooling setpoint shall be employed to prevent rapid cycling of on-off compressors.

G. Miscellaneous Monitoring and Safeties:

1. The DDC system shall monitor the return and supply air temperature of the AHU. Return sensors shall be upstream of where outdoor air from the DOAS unit is injected.
2. If the AHU discharge air temperature indicates heating coil output when the associated valve has been commanded fully closed for longer than 10 minutes while the unit fan continues to run, a 'leaky valve' alarm shall be issued.
3. Filters: Filter pressure drop shall be monitored by the DDC system at each of the two (2) filter banks. The DDC system shall issue a maintenance alarm whenever any particular filter bank's pressure drop exceeds its high limit setpoint.
4. AC Condensate Drain Pan Overflow: The DDC system shall monitor the overflow condition of the AC condensate drain pan, and if condensate reaches the high limit level, the DDC system shall de-energize the condensing unit and shall issue an alarm, along with the reason for the shutdown.

    a. Utilize hardwiring for condensing unit lockout response.

1.14 NON-ENERGY RECOVERY DUCTLESS SPLIT SYSTEM HEAT PUMPS

A. This sequence applies to equipment specified under Section 238126.

B. Packaged Controls: Split systems shall operate using their factory packaged temperature controls and remote wall mounted room controller / thermostat provided with the equipment package, as specified in Section 238126.

1. The room thermostats shall be configured so that local adjustment of heating and cooling setpoints is not permitted / possible.

C. DDC System Scope: The DDC system sub-contractor shall be responsible for powering the unit controls (if not powered by the unit single point connection), mapping split system control /communication points into the DDC system workstation, making control setting adjustments for proper operation with the assistance of the equipment factory representative, commissioning and functionally testing the factory controls, and installing and wiring any field mounted control devices shipped loose and/or not factory wired from the unit's single point power connection.

1. BAS Interface: The DDC system shall be connected to each indoor unit's factory control package through a BACnet MS/TP gateway. The following minimum points shall be mapped into the DDC system for each indoor unit:

    a. Read (output points from split system controls input into the DDC system):

        1) System operating status (on off)
        2) Heat / Cool status
        3) Trouble alarm fault code - code shall also be translated into plain language for display on the DDC system workstation.
        4) Indoor unit fan speed.
        5) Space / return air temperature.

b. Write (output points from the DDC system input into the split system controls):

1) System enable / disable.
2) Space heating temperature setpoint
3) Space cooling temperature setpoint.
4) Indoor unit fan speed.

D. Alarming: The DDC system shall issue an alarm if the room reaches the high or low limit temperature. The DDC system shall issue an alarm if a unit is in a trouble alarm condition.

E. Time of Day Operation and Setpoint Control:

1. Occupied / unoccupied mode control and space temperature setbacks shall be accomplished by the DDC system, through the system on/off and space temperature setpoint 'write' points to the split system equipment package via BACnet MS/TP communications. The DDC system shall utilize the space/return temperature BACnet point from each indoor unit to determine when unoccupied mode heating or cooling is required.
2. Refer to the Article titled "Temperature Control Zone Occupancy Monitoring" for requirements regarding space temperature setpoint reset based on occupancy status and time of day for selected units.

1.15 STAND-ALONE HOT WATER FIN TUBE CONVECTORS

A. This sequence also applies to hot water radiators that have their own associated space thermostat, and do not have an associated AHU.

B. Temperature Control: The DDC system shall monitor the room temperature and shall modulate the control valve open to convector flow on a fall in space temperature. The heating is permitted to operate whenever the OA temperature is below 60 deg. F.

C. Control Setpoint Reset: The room temperature heating setpoint shall vary in accordance with a time of day schedule.

1.16 STAIRWELL CABINET UNIT HEATERS

A. The hot water cabinet unit heaters in the attic shall be controlled by the DDC system. The DDC system shall monitor space temperature and on a fall in space temperature 3 deg. F below setpoint, the unit fan shall be energized and the two-position, three-way valve shall be fully opened to coil flow. Upon the space reaching setpoint temperature, the fan shall be de-energized and the valve shall be fully closed to coil flow. The heater operation shall be locked out if the hot water system is not currently operational.

1. The DDC system shall not permit CUHs to run unless the outdoor air temperature is lower than 55 deg. F.
2. Status monitoring or discharge air temperature monitoring is not required.
3. Recommended space temperature setpoint is a continuous 65 deg. F.
4. The valve shall fail normally open to coil flow.

1.17 ATTIC HORIZONTAL HOT WATER UNIT HEATERS

A. The hot water horizontal unit heaters in the attic shall be controlled by the DDC system. The DDC system shall monitor space temperature and on a fall in space temperature 3 deg. F below

setpoint, the unit fan shall be energized and the two-position, three-way valve shall be fully opened to coil flow. Upon the space reaching setpoint temperature, the fan shall be de-energized and the valve shall be fully closed to coil flow. The heater operation shall be locked out if the hot water system is not currently operational.

1. The DDC system shall not permit HUHs to run unless the outdoor air temperature is lower than 45 deg. F.
2. Status monitoring or discharge air temperature monitoring is not required.
3. Recommended space temperature setpoint is a continuous 55 deg. F.
4. The valve shall fail normally open to coil flow.

1.18 DOMESTIC WATER SERVICE METERING

A. The DDC system shall monitor the domestic water service meter gallons consumption via pulse output.

B. Division of Scope and Coordination with the .3 Prime Contractor:

1. The BAS provider/sub-contractor shall coordinate shall coordinate with the Division 22 Contractor to verify the sizing of domestic water meters. For bidding purposes, a 2" meter shall be assumed.
2. The water meter shall be furnished by the BAS provider / sub-contractor under the .2 Contract to the .3 Contractor, and the meter shall be installed by the .3 Contractor.
3. Refer to the Plumbing Drawings (P-200) for the water meter location.
4. The BAS provider/sub-contractor shall provide control power connections to the water meter transmitter.

1.19 DOMESTIC WATER BOOSTER PUMP MONITORING

A. The DDC system shall connect to the BACnet interface on the packaged controls of the domestic water booster pump package. All available points shall be mapped into the DDC system. The DDC system shall issue an alarm if the booster pump package is in a fault status.

1.20 DOMESTIC HOT WATER SYSTEM MONITORING

A. Water Heater Temperature Monitoring: The DDC system shall monitor the discharge temperature of each of the domestic hot water heaters via a sensor on the supply piping, as well as on the common hot water supply line going into the main mixing valve, and at the supply line downstream of the main mixing valve. The DDC system shall issue an alarm if the domestic hot water supply temperature at any location falls more than 10 degrees below setpoint for longer than 10 minutes. The DDC system shall monitor the hot water recirculation return temperature of the recirculation loop.

B. Recirculation Pump: The DDC system shall have start / stop control over the recirculation pump and shall monitor the pump's status. The DDC system shall issue an alarm whenever the pump fails to run. The DDC system shall operate the pump continuously, and the pump shall only be de-energized by manual command at the workstation.

1.21 STANDBY GENERATOR MONITORING

A. The DDC system shall monitor and display on the workstation the operating status of the emergency generator, the availability of normal power (through contacts on the transfer switch), and the fault (trouble alarm) status of the generator package. The DDC system shall issue an alarm whenever the generator is in a fault status. The DDC system shall monitor the position of each of the automatic transfer switches and shall issue an alarm if normal power is lost.

PART 2 - (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

END OF SECTION