SECTION 23 09 05 - SEQUENCE OF OPERATIONS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Retain or delete this article in all Sections of Project Manual.

B. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes control sequences. Sequence of operation is hereby defined as the manner and method by which various controls and systems function.

B. The requirements for the operation of each type of system are specified in this section and/or on the contract drawings.

1.3 SUBMITTALS

A. The control system supplier/installer shall review all HVAC equipment shop drawings prior to their shop drawing submission. The supplier shall note in the submission that all relative shop drawings have been reviewed prior to submission to the engineer.

B. Shop Drawings: Submit shop drawings containing the following information:

1. Schematic flow diagram of system showing fans, pumps, coils, dampers, valves, and control devices. Label each control device with setting or adjustable range of control.
2. Indicate difference between factory and field wiring.
3. Indicate each control panel required, with internal and external piping and wiring clearly indicated. Provide detail of panel face, including controls, instruments, and labeling.
4. Include verbal description of sequence of operation.
5. Maintenance Data: Include copy of all shop drawings in each maintenance manual.
6. Riser diagrams showing control network layout, communication protocol, and wire types.

C. When preparing submittals and programming, use a room number schedule generated by the architect and/or the owner, which indicates the actual room numbers that will be used when the building is occupied. If the schedule is not available, revise the initial submittal, when a schedule is available, to reflect the proper room numbers.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

3.1 CONTROL SEQUENCES: BUILDING MANAGEMENT SYSTEM

A. The BMS shall include all hardware, software and programming required to fully execute all control sequences and shall monitor and record all control points described in this specification. The BMS shall have the capabilities to perform the control strategies, energy management functions, and building management functions. All BMS software shall reside on the Operator Workstation to be located within the building at a location to be determined by the owner.

1. Set Point Control: The BMS shall have full editing capabilities for any set point listed in these control sequences regardless of whether set point control logic resides in a local control unit or the building management software. All controls shall be capable of fully executing all control sequences in the event of a communication loss between the BMS operator workstation and any local control unit(s).
2. Operating Mode Control: The BMS shall have full 24hr./365-day scheduling capabilities for occupied/unoccupied modes of operation for all systems regardless of whether sequencing logic resides in a local control unit or the building management software. Provide programming that utilizes various global commands for zoning portions of the building as required by the owner. The control system shall be capable of fully executing all schedule sequences in the event of a communication loss between the operator workstation and any local control unit(s).
3. Control Offset: The BMS shall be capable of offsetting the control set points for any heating/cooling system equipment by an operator adjustable amount. This capability will allow for automatic set point changes based on system requirements, such as demand limiting.
4. Alarm Management: The BMS shall monitor, buffer, and direct alarm reports to operator devices and memory files. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of three (3) priority levels shall be provided. Each local control unit as well as the BMS software shall be capable of performing distributed, independent alarm analysis and filtering based on priority level.

    a. The conditions under which alarms need to be acknowledged by an operator, and/or sent to follow-up files for retrieval and analysis at a later date shall be definable by the user.
    b. Report Routing: Alarm, reports, messages, and files will be directed to a user-defined list of operator devices for archiving alarm information. Alarms shall also be automatically directed to a default device in the event a primary device is found to be off-line.
    c. Alarm Messages: In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 65-character alarm message to more fully describe the alarm condition or direct operator response.
    d. Auto-Dial Alarm: The user shall define which critical alarms shall initiate a call to a remote operator device.

5. Historical Data and Trending: The BMS shall be capable of automatically sampling, storing, and displaying system data and as a minimum do so in the flowing ways:

    a. Continuous Point Histories: A point history routine shall continuously and automatically sample the value of all analog and binary inputs and outputs at fifteen-minute intervals. Samples shall be stored for the past 72 hours to allow the user to immediately analyze equipment performance and all problem-related events. History files shall include a continuous record of the last ten status changes or commands for each point.
    b. Control Loop Performance Trends: Operator adjustable resolution sampling of 10-300 seconds in 1-second increments for verification of control loop performance.

c. Extended Sample Period Trends: Measured and calculated analog and binary data shall also be assignable to user-definable trends for the purpose of collecting performance data over extended periods of time. Sample intervals of 1-minute to 2-hours, in 1-minute intervals, shall be provided.
d. Data Storage and Archiving: Trend data shall be uploaded from local unit controllers to the Operator Workstation at user-defined intervals or when the trend buffers become full. All trend data shall be available in disk file form for use in third party personal computer applications.

6. Totalization: The BMS shall be capable of automatically sampling, storing, and displaying totals as follows:

a. Runtime: Automatically accumulate, store, and display runtime hours for binary input and output points as specified in sequence of operations specifications. The totalization routine shall have a sampling resolution of 1-minute or less. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.
b. Analog/Pulse: Automatically sample, calculate, store, and display consumption totals on a daily basis for user selected analog and binary pulse input-type points. The totalization routine shall have a sampling resolution of 1-minute or less. The user shall have the ability to define a warning limit. Unique, user-specified messages shall be generated when the limit is reached.
c. Event: Automatically count, store, and display event occurrences (such as the number of times a pump or fan system is cycled) on a daily basis for user selected events.

3.2 CONTROL SEQUENCES: BOILER SYSTEM SEQUENCE

A. The boilers and lead heating system pump will be enabled by the BMS when the outside air temperature is below 60 deg. F (adjustable) or manually enabled at through the BMS.

B. A Boiler Sequence Control System (BSCS) will be provided by the boiler manufacturer. Refer to the project's applicable Boiler Specification Section.

C. The BSCS will energize the lead system pump. The BMS shall modulate the system pump VFD to maintain the required minimum flow rate to each operating boiler. The minimum flow rate will vary depending on the number of energized boilers and the flow rate required by the boiler manufacture. Verify the required minimum flow with the boiler manufacture. Utilize the electronic flow meter in the piping system to ensure the minimum flow is maintained to each operating boiler.

D. The BSCS will control the leaving water temperature at each boiler and sequence the boilers to, as needed to optimize the efficiency of the system.

E. When the system pump is operating at the required minimum flow rate and the system pressure is above set point, modulate the differential pressure by-pass valve to maintain system differential pressure.

F. Provide controls to monitor and record make-up water flow from the domestic water system to the heating system.

G. Emergency Burner Control: Provide a complete operational system for emergency burner switches, as required by the PA Labor and Industry Code, at all exit doors, to interrupt fuel feed and electric power to all fuel fired equipment located within the boiler room.

H. The BMS shall monitor, record, and display the following monitoring points on a custom graphic at the operator work station:

1. Boiler status, each boiler: indication and alarm.
2. Heating supply and return water temperature, each boiler: indication.
3. Common heating supply and return water temperature: indication.
4. Heating system flow in g.p.m - indication.
5. System bypass valve position: indication.
6. System differential pressure: indication, adjustment, and alarm.
7. Boiler room temperature: indication.
8. Boiler room temperature set point: indication and adjustment.
9. Make-up flow (g.p.m.) from the domestic water system: indication.
10. Display all control points available through the BACnet interface furnished with the boiler control system.

3.3 CONTROL SEQUENCES: CHILLER SYSTEM SEQUENCE

A. The chiller and chilled water pumps will be enabled by the BMS when the outside air temperature is above a fully adjustable set point or when manually enabled through the BMS.

B. On a call for cooling start the lead chilled water system pump. When flow is proven start the chiller. The chiller and system pump shall operate to maintain a chilled water supply temperature of 42 deg. F. (adjustable).

C. Modulate the pump VFD to maintain the required flow to the chiller. The flow rate will vary depending on the number of operating circuits and the minimum flow required by the chiller manufacture. Utilize the electronic flow meter at the pumps to provide the minimum required flow. Coordinate the required minimum flow with the equipment manufacturer to verify the proper flow to the chiller.

D. The BMS shall monitor, record, and display the following points on a custom graphic at the operator workstation:

1. Chiller(s) status: indication and no flow alarm.
2. Chilled water supply and return temperature at each chiller: indication and adjustment.
3. Chilled water system flow: in G.P.M.: indication.
4. Pump status: indication and alarm.
5. Glycol feeder level: indication.
6. System bypass valve position: indication.
7. Exterior piping heat trace: indication
8. Differential pressure across the evaporator: indication.

3.4 CONTROL SEQUENCES: HVAC SYSTEM PUMPS

A. The HVAC system pumps shall be controlled by the BMS.

B. Provide The HVAC system heating pumps shall be controlled by the BMS.

C. Provide lead/lag controls for all redundant pumps. In the event the led pump fails, start the lag pump and alarm the system. Provide for a fully adjustable schedule to alternate the led and lag pumps.

D. Provide the required number of sensors in the piping loop to control the pump VFD's and control the system by-pass valve as necessary for the heating and cooling systems.

E. The BMS shall monitor, record, and display the following monitoring points on a custom graphic at the operator workstation:

1. HVAC pump status: indication, adjustment, and alarm.
2. Lead/Lag pump status - indication, adjustment, and alarm.
3. System by-pass valve position: indication.
4. System differential pressure: indication, adjustment, and alarm.

3.5 CONTROL SEQUENCES: DOMESTIC WATER SYSTEMS

A. Recirculation pumps: Provide controls to start and stop domestic hot water re-circulating water pumps based on a fully adjustable schedule. Provide an alarm should a pump fail. The BMS shall monitor, record and display the following monitoring points on a custom graphic at the operator work station:

1. Status of pumps: indication, adjustment, and alarm.

3.6 CONTROL SEQUENCES: AHU-1, 2, 3, 4, and 6.

A. The BMS installer shall review the packaged air handling unit (AHU-1, 2, 3, and 4) and modular air handling unit (AHU-6) shop drawings prior to submittal of control shop drawings to the Engineer. The packaged units may be provided with factory mounted control components. The unit controller shall be provided by the BMS installer. The BMS installer shall provide additional controls and modifications where required to ensure the units will function as indicated in the sequence.

B. The air handling units and systems serve areas conditioned with fan-powered and shutoff type variable air volume units. Each unit contains a variable speed supply fan(s), variable speed exhaust fan(s), energy recovery, hydronic pre-heat coil, chilled water coil, filters, air flow monitoring, and bipolar ionization air purification, as well as other components.

C. The unit shall be controlled by the BMS and shall be indexed to the occupied and unoccupied settings at the fully adjustable programmed times. Provide optimal start/stop programming.

D. Refer to variable air volume terminal unit sequences for requirements on room sensors such as temperature and humidity sensors.

E. Freeze Protection: Provide a freeze stat, with manual reset, serpentined across the leaving air side of the heating coil. Provide programming per the following sequence if the leaving air temperature falls below 35 deg. F (adjustable):

1. Signal an alarm on the operator workstation.
2. Close the outdoor air dampers.
3. Fully open the heating coil control valve.
4. Stop the fans.

F. In unoccupied modes provide controls to monitor the temperature in the mixed air section of the air handling unit. When the outdoor air temperature is below 35 deg. F. (adjustable) and the temperature in the mixed air section falls below 35 deg. open the heating coil control valve to maintain a temperature of 40 Deg. F (adjustable) in the unit section.

G. Provide control wiring between the unit starter and a relay furnished by the electrical contractor to allow for fan(s) shut down when the fire alarm system activates. If activated close all outdoor air dampers.

H. Provide fully modulating heating control valves that fail in the open position. Provide fully modulating chilled water control valves that fail in the last position. Outdoor air dampers are to fail in the closed position with return dampers failing in the open position.

I. Provide an analog transducer to monitor and record pressure drop across the MERV 13 filters in the air-handling unit. An alarm will be activated at the BMS workstation if the actual filter pressure drop exceeds the dirty filter pressure drop established by the TAB Contractor.

J. Provide controls to detect and eliminate frost accumulation on the energy recovery wheel.

K. Fan Pressure Optimization Control: At a frequency of once every 2 minutes, the BMS shall monitor the damper position of all VAV terminal units. The BMS shall calculate a new supply fan duct static pressure set point based on the position of the furthest open VAV damper, and send this newly-calculated set point to the AHU controller. When any VAV damper is more than 75% (adjustable) open, the supply fan duct static pressure set point shall be reset upward by 5% until no damper is more than 75% (adjustable) open or the static pressure set point has reset to the maximum setting. When all VAV dampers are less than 65% (adjustable) open, the supply fan duct static pressure set point shall be reset downward by 5% until at least one damper is more than 65% (adjustable) open or the static pressure set point has reset to the minimum setting.

L. Duct System Static Pressure Safety: Provide supply duct high static pressure sensors to stop the unit fan(s) and alarm the system if the supply duct static pressure is above the high limit set point. The sensor shall be hard wired and have manual reset. The TABC will determine the location of the sensors. The initial duct static pressure set point shall be +1.25" w.c. The TABC will determine the final static pressure set point.

M. Provide a high static pressure sensor, located at the supply fan discharge. The sensor is to be hard wired with manual reset. The initial set point for this sensor is to be +3.0" w.c. with final adjustment by the TABC Contractor.

N. Ventilation Optimization Control: The actual outdoor air flow shall be sensed at the outdoor air intake of the air handling unit and controlled to an air flow set point determined according to ASHRAE Standard 62.1. When the BMS indicates the air handling unit is occupied, the required outdoor airflow for that system shall equal the design outdoor airflow. The required outdoor-air fraction (current required outdoor airflow divided by the current primary airflow) shall be continuously calculated for each VAV terminal unit. At a frequency of once every 2 minutes, the BMS shall gather this data from all VAV terminal units, calculate the minimum required outdoor airflow for the system according to ASHRAE 62.1, and send this newly-calculated outdoor airflow set point to the AHU controller. Monitor ventilation air flow c.f.m.

O. Unoccupied heating cycle:

1. The supply and exhaust unit fans will be off. The outdoor air damper closed and the return air damper open. The energy recovery wheel will be off.
2. Refer to variable air volume sequences for control requirements.

P. Unoccupied cooling cycle: Two modes of operation shall be available. One mode is to have no cooling with all fans and the energy recovery wheel off and all dampers closed. The second choice is for an adjustable higher space cooling set point, which is described as follows:

1. The supply and exhaust unit fans will be off. The outdoor air damper closed and the return air damper open. The energy recovery wheel will be off.
2. When the space temperature in any area is above the unoccupied set point of 80 deg. F. (adjustable), start the air handling unit supply fan and modulate the fan speed to maintain the duct static pressure setting. Modulate the AHU's cooling coil control valve to maintain a leaving air temperature of 54 degrees F (adjustable).

3. The outside air damper will remain closed. The return air damper shall remain full open. The energy recovery wheel will remain off and the return air flow will bypass the energy recovery wheel. When setback temperature has been restored, reverse this sequence.
4. Refer to variable air volume sequences for control requirements.
5. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor spaces, allow the unit to operate in an economizer mode. Modulate the unit's supply fan to maintain duct static pressure. Modulate the exhaust fan to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable). Modulate the outdoor air damper(s) to maintain a fully adjustable leaving air temperature with the initial set point of 55 degrees F.

Q. Occupied Heating Cycle:

1. Warm-up: provide optimal start through the BMS to index the respective zone to the occupied status. At this time, the unit will operate in the same mode as the unoccupied heating cycle. When the space temperatures reach the occupied set point the unit will operate in the occupied heating cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating as required to maintain the duct static pressure setting. Modulate the heating coil control valve to maintain a fully adjustable leaving air temperature with an initial set point of 65 degrees F. (adjustable).
3. Modulate the outdoor air damper to provide Ventilation Optimization Control. The exhaust fan shall modulate to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable).
4. When the outdoor air temperature is below 50 degrees (adjustable) the energy recovery wheel will energize and all outdoor air will flow through the energy recovery wheel. The air handling unit's by-pass dampers will be closed. The exhaust fan shall modulate to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable).

R. Occupied Cooling Cycle:

1. Cool-down: provide optimal start through the BMS to index the respective zone to the occupied status. At this time, the unit will operate in the same mode as the unoccupied cooling cycle. When the space temperature reaches the occupied set point the unit will operate in the occupied cooling cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating as required to maintain the duct static pressure setting.
3. Modulate the outdoor air damper to provide Ventilation Optimization Control. The exhaust fan shall modulate to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable).
4. When the outdoor air temperature is above 58 degrees (adjustable) the energy recovery wheel will energize and all outdoor air will by-pass the energy recovery wheel. The exhaust fan shall modulate to maintain a set building differential pressure with relationship to the atmosphere of no more than +0.02" w.c. (adjustable).
5. Provide programming to reset the supply air temperature based on the outdoor air temperature by modulating the cooling coil control valve. The set points shall be fully adjustable. Provide the following initial set points:

    a. Outdoor air temperature above 85 deg. F. – 54 deg. LAT.
    b. Outdoor air temperature 72 to 84 deg. F. – 56 deg. LAT.
    c. Outdoor air temperature 57 to 71 deg. F – 58 deg. LAT.

6. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor spaces, allow the unit to operate in an economizer mode. Modulate the unit's supply fan to maintain duct static pressure. Modulate the exhaust fan to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable). Modulate the outdoor air damper(s) to maintain a fully adjustable leaving air temperature with the initial set point of 54 degrees F.

S. Energy Recovery: During occupied cycles, energize the energy recovery wheel when the outdoor air temperature is below 60 deg. or above 80 deg. F. The temperature set points are to be adjustable. When the wheel is on, all outdoor air will flow through the energy recovery wheel. The exhaust fan shall modulate to match the outdoor airflow, minus 10%, and shall only increase past this amount if the building differential pressure with relationship to the atmosphere is greater than +0.02" w.g. (adjustable). Coordinate the locations of the space pressure sensor and the referenced sensor with the TABC. Position the bypass dampers in the energy recovery section as required.

T. Dehumidification Mode: The air handling unit will operate in both the occupied and unoccupied modes to provide dehumidification. During occupied mode, the unit shall operate in dehumidification mode when the return air is above 60% RH and shall terminate when below 55%. Provide a minimum of two space temperature humidity sensors located in representative spaces within area served to enable and disable dehumidification mode when unit is unoccupied.

1. Modulate the cooling coil control valve to maintain 54 deg. discharge air temperature.
2. All associated VAV terminal units shall index to cooling airflow.
3. Modulate VAV terminal unit reheat coils to maintain space temperature setpoints.
4. Dehumidification mode shall only be enabled when boilers are operating.
5. Also refer to VAV sequences for additional requirements.

U. The BMS shall display the following monitoring points on a custom graphic at the operator work station:

1. System status (occupied/unoccupied): indication and adjustment.
2. Supply fan status: indication, adjustment and alarm.
3. Exhaust fans status: indication, adjustments and alarm.
4. V.F.D. status (both fans): indication and alarm.
5. Energy recovery wheel status: indication and alarm.
6. Smoke detector status: indication and alarm.
7. Freezestat status: indication and alarm.
8. MERV 13 filter differential pressure: indication and alarm.
9. Supply duct static pressure setting: indication and alarm.
10. Energy recovery wheel entering air temperature: indication.
11. Energy recovery wheel leaving air temperature: indication.
12. Pre-heat coil control valve position: indication and adjustment.
13. Cooling coil control valve position: indication and adjustment.
14. Unit supply air temperature: indication and adjustment.
15. Unit return air temperature: indication.
16. Outdoor air c.f.m.: indication.
17. Building pressurization: indication and adjustment.
18. Bipolar Ionization generator status: indication.

3.7 CONTROL SEQUENCES: AHU-5 and 7.

A. The system is a single zone variable air volume system. The air handling unit contains a variable speed supply, chilled-water cooling coil, hydronic pre-heat coil, duct-mounted reheat coil, filters, air flow monitoring, and bipolar ionization air purification, as well as other components.

B. The unit shall be controlled by the BMS and shall be indexed to the occupied and unoccupied settings at the fully adjustable programmed times. Provide optimal start/stop programming.

C. Provide a temperature/humidity sensor with adjustable set points. The minimum and maximum set points shall be set through the BMS.

D. Freeze Protection: Provide a freeze stat, with manual reset, serpentined across the leaving air side of the heating coil and provide programming per the following sequence if the leaving air temperature falls below 35 deg. F. (adjustable):

1. Signal an alarm on the operator workstation.
2. Close the outdoor air dampers and open the return air damper.
3. Fully open the heating coil control valve.
4. Stop the fan.

E. Provide control wiring between the unit starter and a relay furnished by the electrical contractor to allow for fan(s) shut down when the fire alarm system activates. If activated close all outdoor air dampers.

F. Provide fully modulating heating valves that are to fail in the open position. Control valves on the duct mounted reheat coils shall fail in the last position. Provide fully modulating cooling valves that are to fail in the last position. Outdoor air dampers and relief vent dampers are to fail in the closed position with return dampers failing in the open position.

G. Provide a transducer to monitor and record pressure drop across the MERV 13 filters in the air-handling unit. An alarm will be activated at the BMS workstation if the actual filter pressure drop exceeds the dirty filter pressure drop established by the TAB Contractor.

H. Provide CO2 Control. To assure proper operation, the controls installer shall re-calibrate the CO2 controller six (6) months after acceptance of the control system to correct any deviations as a result of drift. The CO2 controller shall include a self-calibrating feature with a programmed schedule to re-calibrate the CO2 controller at least once every seven days. Re-calibration shall occur during unoccupied periods.

I. Unoccupied heating cycle:

1. The air handling unit fan will be off. Outdoor air damper will be closed and the return air damper open.
2. When the space temperature falls below the unoccupied set point temperature of 60 deg. F. (adjustable) start the supply fan at full speed and open the preheat coil control valve to provide a 95 deg. F. leaving air temperature.
3. The outside air damper will remain closed. The return air damper shall remain fully open. When setback temperature has been restored, reverse this sequence.

J. Unoccupied cooling cycle: Two modes of operation shall be available. One mode is to have no cooling with all fans off and the outside air damper closed. The second choice is for a higher space cooling set point, which is described as follows:

1. The air handling unit fan will be off. Outdoor air damper will be closed and the return air damper open.
2. When the space temperature rises above the unoccupied set point of 80 deg. F. (adjustable) start the supply fan at the minimum speed and open the cooling coil control valve to supply a 54 deg. F. leaving air temperature. If required to maintain space temperature slowly increase the fan speed and simultaneously modulate open the cooling coil control valve to maintain a 54 deg. F. (adjustable) leaving air temperature.
3. The outside air damper will remain closed. The return air damper shall remain fully open. When setback temperature has been restored, reverse this sequence.

4. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor space, allow the unit to operate in an economizer mode. Start the supply fan at the minimum speed and open the outdoor air damper to provide a 54 deg. F. (adjustable) leaving air temperature. If required to maintain space temperature, slowly increase the supply fan speed, and simultaneously modulate open the outdoor air damper to maintain a 54 deg. F. leaving air temperature. Modulate the associated relief vent damper to maintain a building pressure differential, with relationship to the atmosphere, of no more than +0.02" w.c. (adjustable). Close the chilled water coil control valve when the system is in an economizer mode.

K. Occupied heating cycle:

1. Warm-up: provide optimal start through the BMS to index the respective zone to the occupied status. At this time the unit will operate in the same mode as the unoccupied heating cycle. When the space temperature reaches the occupied set point the unit will operate in the occupied cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating from low to high speed to maintain the space temperature. Modulate the preheat coil control valve in unison with the supply fan VFD, to maintain a leaving air temperature of 95 deg. F. (adjustable).
3. Provide ventilation control per the CO2 sequence.

L. Occupied cooling cycle:

1. Cool-down: provide optimal start through the BMS to index the respective zone to the occupied status. At this time the unit will operate in the same mode as the unoccupied cooling cycle. When the space temperature reaches the occupied set point the unit will operate in the occupied cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating from low to high speed to maintain space temperature. The cooling coil control valve shall modulate in unison with the supply fan to maintain a 54 deg. F. (adjustable) leaving air temperature.
3. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor space, allow the unit to operate in an economizer mode. Start the supply fan at the minimum speed and open the outdoor air damper to provide a 54 deg. F. (adjustable) leaving air temperature. If required to maintain space temperature, slowly increase the supply fan speed, and simultaneously modulate open the outdoor air damper to maintain a 54 deg. F. leaving air temperature. Modulate the associated relief vent damper to maintain a building pressure differential, with relationship to the atmosphere, of no more than +0.02" w.c. (adjustable). Close the chilled water coil control valve when the system is in an economizer mode.
4. Provide ventilation control per the CO2 sequence.

M. CO2 Ventilation Control: Provide ventilation control during the occupied cycles. When the space is indexed to the occupied cycle open the outdoor air damper to minimum outdoor airflow as indicated on the drawings. If the space CO2 controller senses an increased CO2 level above 800 p.p.m. slowly modulate open the outside air damper to maintain the space CO2 level below 1000 p.p.pm. At any time during the occupied cycle the outdoor air damper shall not open past the position to allow more than the scheduled amount of design outside air, as indicated on the drawing schedule, unless the unit is in an economizer cycle. Modulate the associated relief vent damper to maintain a building pressure differential, with relationship to the atmosphere, of no more than +0.02" w.c. (adjustable).

N. Makeup Air Ventilation Control (AHU-5 only): Anytime the kitchen cooking hood exhaust fan (KEF-1) is operating, provide ventilation at the design outdoor airflow indicated on the schedule in order to provide makeup air for the kitchen.

O. Dehumidification: At any time the space humidity is above 60% RH, run the supply fan at cooling airflow, open the cooling coil control valve to provide a 54 deg. F. (adjustable) leaving air temperature and modulate open the duct-mounted reheat coil control valve to maintain the space temperature set point. When the space humidity level falls below 55% RH, reverse the sequence. Dehumidification shall be available during unoccupied cycles with the outdoor air damper closed.

P. The BMS shall monitor, record, and display the following monitoring points on a custom graphic at the operator work station:

1. System status (Occupied / Unoccupied): indication and adjustment.
2. Supply fan status: indication, adjustment, and alarm.
3. V.F.D. status: indication and alarm.
4. Preheat coil control valve position: indication and adjustment.
5. Cooling coil control valve position: indication and adjustment.
6. Reheat coil control valve position: indication and adjustment.
7. Supply air temperature: indication and adjustment.
8. Return air temperature: indication.
9. Mixed air temperature: indication
10. Outdoor air c.f.m.: indication.
11. Smoke detector status: indication and alarm.
12. Freezestat status: indication and alarm.
13. Filter differential pressure: indication and alarm.
14. Building pressurization: indication and adjustment.
15. Space temperature set point: indication and adjustment.
16. Space temperature: indication and alarm.
17. Space humidity set point: indication, adjustment.
18. Space humidity level: indication and alarm.
19. Space CO2 set point: indication and adjustment.
20. Space CO2 level: indication and alarm.
21. Bipolar Ionization generator status: indication.

3.8 CONTROL SEQUENCES: RTU-1

A. The BMS installer shall review the packaged air handling unit shop drawings prior to submittal of control shop drawings to the Engineer. The packaged units may be provided with factory mounted control components. The unit controller shall be provided by the BMS installer. The BMS installer shall provide additional controls and modifications where required to ensure the units will function as indicated in the sequence.

B. The packaged air handling units and systems serve areas conditioned with shutoff type variable air volume units. The units contain a variable speed supply fan, barometric relief, hydronic pre-heat coil, DX cooling coil, filters, air flow monitoring, and bipolar ionization air purification, as well as other components.

C. The unit shall be controlled by the BMS and shall be indexed to the occupied and unoccupied settings at the fully adjustable programmed times. Provide optimal start/stop programming.

D. Refer to variable air volume sequences for requirements on room sensors such as thermostats, and humidistats.

E. Freeze Protection: Provide a freeze stat, with manual reset, serpentined across the leaving air side of the heating coil. Provide programming per the following sequence if the leaving air temperature falls below 35 deg. F (adjustable):

1. Signal an alarm on the operator workstation.
2. Close the outdoor air dampers.
3. Fully open the heating coil control valve.
4. Stop the fans.

F. In unoccupied modes provide controls to monitor the temperature in the mixed air section of the air handling unit. When the outdoor air temperature is below 35 deg. F. (adjustable) and the temperature in the mixed air section falls below 35 deg. open the heating coil control valve to maintain a temperature of 40 Deg. F (adjustable) in the unit section.

G. Provide control wiring between the unit starter and a relay furnished by the electrical contractor to allow for fan(s) shut down when the fire alarm system activates. If activated close all outdoor air dampers.

H. Provide fully modulating heating control valves that fail in the open position. Outdoor air dampers are to fail in the closed position with return dampers failing in the open position.

I. Provide an analog transducer to monitor and record pressure drop across the MERV 13 filters in the air-handling unit. An alarm will be activated at the BMS workstation if the actual filter pressure drop exceeds the dirty filter pressure drop established by the TAB Contractor.

J. Fan Pressure Optimization Control: At a frequency of once every 2 minutes, the BMS shall monitor the damper position of all VAV terminal units. The BMS shall calculate a new supply fan duct static pressure set point based on the position of the furthest open VAV damper, and send this newly-calculated set point to the AHU controller. When any VAV damper is more than 75% (adjustable) open, the supply fan duct static pressure set point shall be reset upward by 5% until no damper is more than 75% (adjustable) open or the static pressure set point has reset to the maximum setting. When all VAV dampers are less than 65% (adjustable) open, the supply fan duct static pressure set point shall be reset downward by 5% until at least one damper is more than 65% (adjustable) open or the static pressure set point has reset to the minimum setting.

K. Duct System Static Pressure Safety: Provide supply duct high static pressure sensors to stop the unit fan(s) and alarm the system if the supply duct static pressure is above the high limit set point. The sensor shall be hard wired and have manual reset. The TABC will determine the location of the sensors. The initial duct static pressure set point shall be +1.25" w.c. The TABC will determine the final static pressure set point.

L. Provide a high static pressure sensor, located at the supply fan discharge. The sensor is to be hard wired with manual reset. The initial set point for this sensor is to be +3.0" w.c. with final adjustment by the TABC Contractor.

M. Ventilation Optimization Control: The actual outdoor air flow shall be sensed at the outdoor air intake of the air handling unit and controlled to an air flow set point determined according to ASHRAE Standard 62.1. When the BMS indicates the air handling unit is occupied, the required outdoor airflow for that system shall equal the design outdoor airflow. The required outdoor-air fraction (current required outdoor airflow divided by the current primary airflow) shall be continuously calculated for each VAV terminal unit. At a frequency of once every 2 minutes, the BMS shall gather this data from all VAV terminal units, calculate the minimum required outdoor airflow for the system according to ASHRAE 62.1, and send this newly-calculated outdoor airflow set point to the AHU controller. Monitor ventilation air flow c.f.m.

N. Unoccupied heating cycle:

1. The supply and exhaust unit fans will be off. The outdoor air damper closed and the return air damper open.
2. When the space temperature in a pre-determined, fully adjustable number of areas, is below the unoccupied adjustable set point of 60 deg. F. (adjustable), start the unit's supply fan and modulate the fan speed to maintain the duct static pressure setting. Open and modulate the heating coil control valve to maintain a 95 deg. F. leaving air temperature. The outside air damper will remain closed. The return air damper shall remain full open. When setback temperature has been restored, reverse this sequence.

O. Unoccupied cooling cycle: Two modes of operation shall be available. One mode is to have no cooling with all fans and the energy recovery wheel off and all dampers closed. The second choice is for an adjustable higher space cooling set point, which is described as follows:

1. The supply and exhaust unit fans will be off. The outdoor air damper closed and the return air damper open.
2. When the space temperature in any area is above the unoccupied set point of 80 deg. F. (adjustable), start the air handling unit supply fan and modulate the fan speed to maintain the duct static pressure setting. Modulate the AHU's DX cooling to maintain a leaving air temperature of 54 degrees F (adjustable). The outside air damper will remain closed. The return air damper shall remain full open. When setback temperature has been restored, reverse this sequence.
3. The VAV terminal units will function per the unoccupied cooling sequence.
4. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor spaces, allow the unit to operate in an economizer mode. Modulate the unit's supply fan to maintain duct static pressure. The unit's barometric relief section will function to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable). Modulate the outdoor air damper(s) to maintain a fully adjustable leaving air temperature with the initial set point of 55 degrees F. The DX cooling will not function when the system is in an economizer mode.

P. Occupied Heating Cycle:

1. Warm-up: provide optimal start through the BMS to index the respective zone to the occupied status. At this time, the unit will operate in the same mode as the unoccupied heating cycle. When the space temperatures reach the occupied set point the unit will operate in the occupied heating cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating as required to maintain the duct static pressure setting. Modulate the heating coil control valve to maintain a fully adjustable leaving air temperature with an initial set point of 58 degrees F. (adjustable).
3. Modulate the outdoor air damper to provide Ventilation Optimization Control. The unit's barometric relief section will function to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable).

Q. Occupied Cooling Cycle:

1. Cool-down: provide optimal start through the BMS to index the respective zone to the occupied status. At this time, the unit will operate in the same mode as the unoccupied cooling cycle. When the space temperature reaches the occupied set point the unit will operate in the occupied cooling cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating as required to maintain the duct static pressure setting.
3. Modulate the outdoor air damper to provide Ventilation Optimization Control. The unit's barometric relief section will function to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable).
4. Provide programming to reset the supply air temperature based on the outdoor air temperature by modulating the DX cooling. The set points shall be fully adjustable. Provide the following initial set points:

    a. Outdoor air temperature above 85 deg. F. – 54 deg. l.a.t.
    b. Outdoor air temperature 72 to 84 deg. F. – 56 deg. l.a.t.
    c. Outdoor air temperature 57 to 71 deg. F – 58 deg. l.a.t.

5. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor spaces, allow the unit to operate in an economizer mode. Modulate the unit's supply fan to maintain duct static pressure. The unit's barometric relief section will function to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable). Modulate the outdoor air damper(s) to maintain a fully adjustable leaving air temperature with the initial set point of 54 degrees F. The DX cooling will not function when the system is in an economizer mode.

R. Dehumidification Mode: The air handling unit will operate in both the occupied and unoccupied modes to provide dehumidification. During occupied mode, the unit shall operate in dehumidification mode when the return air is above 60% RH and shall terminate when below 55%. Provide a minimum of two space temperature humidity sensors located in representative spaces within area served to enable and disable dehumidification mode when unit is unoccupied.

1. Modulate the cooling coil control valve to maintain 54 deg. discharge air temperature.
2. All associated VAV terminal units shall index to cooling airflow.
3. Modulate VAV terminal unit reheat coils to maintain space temperature setpoints.
4. Dehumidification mode shall only be enabled when boilers are operating.
5. Also refer to VAV sequences for additional requirements.

S. The BMS shall display the following monitoring points on a custom graphic at the operator work station:

1. System status (occupied/unoccupied): indication and adjustment.
2. Supply fan status: indication, adjustment, and alarm.
3. V.F.D. status: indication and alarm.
4. Smoke detector status: indication and alarm.
5. Freezestat status: indication and alarm.
6. MERV 13 filter differential pressure: indication and alarm.
7. Supply duct static pressure setting: indication and alarm.
8. Heating coil control valve position: indication and adjustment.
9. Unit supply air temperature: indication and adjustment.
10. Unit return air temperature: indication.
11. Outdoor air c.f.m.: indication.
12. Building pressurization: indication and adjustment.
13. Bipolar Ionization generator status: indication.

3.9 CONTROL SEQUENCES: RTU-2

A. The BMS installer shall review the packaged air handling unit shop drawings prior to submittal of control shop drawings to the Engineer. The packaged units may be provided with factory mounted control components. The unit controller shall be provided by the BMS installer. The BMS installer shall provide additional controls and modifications where required to ensure the units will function as indicated in the sequence.

B. The packaged air handling unit is a single zone unit and contains a variable speed supply fan, barometric relief, hydronic pre-heat coil, DX cooling coil, hot-gas reheat, filters, and bipolar ionization air purification, as well as other components. Bipolar ionization air purification is an alternate bid.

C. The unit shall be controlled by the BMS and shall be indexed to the occupied and unoccupied settings at the fully adjustable programmed times. Provide optimal start/stop programing.

D. Provide a space thermostat/sensor and humidistat. The minimum and maximum space set points shall be set at the operator work station.

E. Freeze Protection: Provide a freeze stat, with manual reset, serpentined across the leaving air side of the heating coil. Provide programming per the following sequence if the leaving air temperature falls below 35 deg. F (adjustable):

1. Signal an alarm on the operator workstation.
2. Close the outdoor air dampers.
3. Fully open the heating coil control valve.
4. Stop the fans.

F. In unoccupied modes provide controls to monitor the temperature in the mixed air section of the air handling unit. When the outdoor air temperature is below 35 deg. F. (adjustable) and the temperature in the mixed air section falls below 35 deg. open the heating coil control valve to maintain a temperature of 40 Deg. F (adjustable) in the unit section.

G. Provide control wiring between the unit starter and a relay furnished by the electrical contractor to allow for fan(s) shut down when the fire alarm system activates. If activated close all outdoor air dampers.

H. Provide fully modulating heating control valves that fail in the open position. Provide fully modulating chilled water control valves that fail in the last position. Outdoor air dampers are to fail in the closed position with return dampers failing in the open position.

I. Provide an analog transducer to monitor and record pressure drop across the MERV 13 filters in the air-handling unit. An alarm will be activated at the BMS workstation if the actual filter pressure drop exceeds the dirty filter pressure drop established by the TAB Contractor.

J. Unoccupied heating cycle:

1. The supply fan will be off, the outdoor air damper closed and the return air damper open.
2. When the space temperature falls below the fully adjustable unoccupied set point temperature of 60 deg. F. start the supply fan at full speed and open the heating coil control valve to provide a 95 deg. F. leaving air temperature. When the unoccupied set point temperature has been restored, reverse the above sequence.

K. Unoccupied cooling cycle: Two modes of operation shall be available. One mode is to have no cooling with all fans off and the outside air damper closed. The second choice is for a higher space cooling set point, which is described as follows:

1. The supply fan will be off, the outdoor air damper closed and the return air damper open.
2. When the space temperature rises above the unoccupied set point of 80 deg. F. (adjustable) start the supply fan at low speed and energize the DX cooling to supply a 54 deg. F. leaving air temperature. If required to maintain space temperature, slowly increase the fan speed and simultaneously increase the DX cooling to maintain a 54 deg. F. (adjustable) leaving air temperature. When the unoccupied space temperature has been restored, reverse the above sequence.
3. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor space, allow the unit to operate in an economizer mode. Start the supply fan at low speed and open the outdoor air damper to provide a 54 deg. F. (adjustable) leaving air temperature. If required to maintain space temperature, increase the supply fan speed and simultaneously modulate open the outdoor air damper to maintain a 54 deg. F. leaving air temperature. The unit’s barometric relief section will function to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable). The DX cooling will not function when the system is in an economizer mode.

L. Occupied heating cycle:

1. Warm-up: provide optimal start through the BMS to index the respective zone to the occupied status. At this time the unit will operate in the same mode as the unoccupied heating cycle. When the space temperature reaches the occupied set point the unit will operate in the occupied cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating from low to high speed to maintain the space temperature. Modulate the heating coil control valve in unison with the supply fan VFD, to maintain a leaving air temperature of 95 deg. F. (adjustable).

M. Occupied cooling cycle:

1. Cool-down: provide optimal start through the BMS to index the respective zone to the occupied status. At this time, the unit will operate in the same mode as the unoccupied cooling cycle. When the space temperature reaches the occupied set point the unit will operate in the occupied cooling cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating from low to high speed to maintain space temperature. Modulate the DX cooling in unison with the supply fan to maintain a 54 deg. F. (adjustable) leaving air temperature. The exhaust fan will modulate to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.g. Coordinate the locations of the space pressure sensor and the referenced sensor with the TABC.
3. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor space, allow the unit to operate in an economizer mode. Start the supply fan at low speed and open the outdoor air damper to provide a 54 deg. F. (adjustable) leaving air temperature. If required to maintain space temperature, increase the supply fan speed and simultaneously modulate open the outdoor air damper to maintain a 54 deg. F. leaving air temperature. The unit's barometric relief section will function to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable). The DX cooling will not function when the system is in an economizer mode.

N. Dehumidification: At any time the space humidity is above the set point of the space humidistat, run the supply fan at full speed, energize the DX cooling to provide a 54 deg. F. (adjustable) leaving air temperature and energize the hot-gas reheat to maintain the space temperature set point. When the space humidity level falls below the space sensor set point reverse the sequence. Dehumidification shall be available during unoccupied cycles with the outdoor air damper closed.

O. The BMS monitor, record, and display the following monitoring points on a custom graphic at the operator work station:

1. System status (occupied / unoccupied): indication and adjustment.
2. Supply fan status: indication, adjustment, and alarm.
3. VFD status: indication and alarm.
4. Smoke detector status: indication and alarm.
5. Freezestat status: indication and alarm.
6. MERV 13 filter differential pressure: indication and alarm.
7. Heating coil control valve position: indication and adjustment.
8. Unit supply leaving air temperature: indication and adjustment.
9. Unit return air temperature: indication.
10. Outdoor air c.f.m.: indication.
11. Building pressurization: indication and adjustment.
12. Bipolar Ionization generator status: indication.
13. Space temperature set point: indication and adjustment.
14. Space temperature: indication.
15. Space humidity set point: indication and adjustment.
16. Space humidity level: indication and alarm.

3.10 CONTROL SEQUENCES: PAH-1 thru 6 and 8

A. The units are single zone units with a variable speed supply air fan, hydronic pre-heat coil, chilled water cooling, duct-mounted hydronic reheat coils, filters, and dampers, as well as other components.

B. The unit(s) shall be controlled by the BMS and shall be indexed to the occupied and unoccupied settings at the fully adjustable programmed times. Provide optimal start / stop programming.

C. Provide a space thermostat/sensor and humidistat with adjustable temperature and humidity set points. The minimum and maximum space set points shall be set through the BMS.

D. Freeze Protection: Provide a freeze stat, with manual reset, serpentined across the leaving air side of the heating coil and provide programming per the following sequence if the leaving air temperature falls below 35 Degrees F (adjustable):

1. Signal an alarm on the operator workstation.
2. Close the outdoor air dampers and open the return air damper.
3. Fully open the heating coil control valve.
4. Stop the fan.

E. Provide fully modulating heating valves that are to fail in the open position. Control valves on the duct mounted reheat coils shall fail in the last position. Provide fully modulating cooling valves that are to fail in the last position. Outdoor air dampers and relief vent dampers are to fail in the closed position with return dampers failing in the open position.

F. Unoccupied heating cycle:

1. The outside air damper and any relief dampers will be closed and the return air damper fully open. The supply air fan will be off.
2. When the space temperature falls below the fully adjustable unoccupied set point temperature of 60 degrees F. start the supply fan at full speed and open the heating coil control valve to provide a 95-degree F. (adjustable) leaving air temperature. When the unoccupied set point temperature has been restored, reverse the above sequence.

G. Unoccupied cooling cycle: Two modes of operation shall be available. One mode is to have no cooling with all fans off and the outside air damper closed. The second choice is for a higher space cooling set point, which is described as follows:

1. The outside air damper and any relief dampers will be closed and the return air damper fully open. The supply air fan will be off.
2. When the space temperature rises above the fully adjustable unoccupied set point temperature of 80 degrees F. (adjustable) start the supply fan at low speed and open the chilled water valve to supply a 54-degree F. (adjustable) leaving air temperature. If required to maintain the space temperature, increase the fan speed and simultaneously modulate open the cooling coil control valve to maintain a 54-degree F. leaving air temperature. When the unoccupied space temperature has been restored, reverse the above sequence.
3. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor space, allow the unit to operate in an economizer mode. Start the supply fan at low speed and open the outdoor air damper to provide a 54-degree F (adjustable) leaving air temperature. If required to maintain the space temperature increase the supply fan speed and simultaneously modulate open the outdoor air damper to maintain a 54-degree F. leaving air temperature. Modulate open the relief vents to maintain a building pressure differential, with relationship to the atmosphere, of no more than +0.02" w.c. (adjustable). The chilled water cooling will not function when the system is in an economizer mode.

H. Occupied heating cycle:

1. Warm-up: provide optimal start/stop programing through the BMS to index the respective zone to the occupied status and initiate morning warm-up. At this time the unit will operate in the same mode as the unoccupied heating cycle. When the space temperature reaches the fully adjustable occupied set point the unit will operate in the occupied cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating from low to high speed to maintain the space temperature. Modulate the heating coil control valve in unison with the supply fan to maintain a leaving air temperature of 95 degrees F. (adjustable) and maintain the space temperature set point.

I. Occupied cooling cycle:

1. Cool-down: provide optimal start through the BMS to index the respective zone to the occupied status and initiate morning cool-down. At this time, the unit will operate in the same mode as the unoccupied cooling cycle. When the space temperature reaches the fully adjustable occupied set point the unit will operate in the occupied heating cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating from low to high speed to maintain space temperature. The cooling coil control valve will modulate in unison with the supply fan, to maintain a 54-degree F. (adjustable) leaving air temperature.
3. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor space, allow the unit to operate in an economizer mode. Start the supply fan at low speed and open the outdoor air damper to provide a 54-degree F (adjustable) leaving air temperature. If required to maintain the space temperature increase the supply fan speed and simultaneously modulate open the outdoor air damper to maintain a 54-degree F. leaving air temperature. Modulate open the relief vents to maintain a building pressure differential, with relationship to the atmosphere, of no more than +0.02" w.c. (adjustable). The chilled water cooling will not function when the system is in an economizer mode.

J. Dehumidification: At any time the space humidity is above 60% RH, run the supply fan at cooling airflow, open the cooling coil control valve to provide a 54 deg. F. (adjustable) leaving air temperature and modulate open the duct-mounted reheat coil control valve to maintain the space temperature set point. When the space humidity level falls below 55% RH, reverse the sequence. Dehumidification shall be available during unoccupied cycles with the outdoor air damper closed.

K. The BMS shall monitor, record, and display the following points on a custom graphic at the operator workstation:

1. System status: indication and adjustment
2. Fan status: indication, adjustment, and alarm.
3. Fan speed: indication and adjustment.
4. Preheat coil control valve position: indication and adjustment.
5. Cooling coil control valve position: indication and adjustment.
6. Reheat coil control valve position: indication and adjustment.
7. Supply air temperature: indication and adjustment.
8. Return air temperature: indication.
9. Freezestat status: indication and alarm.
10. Space temperature set point: indication and adjustment.
11. Space temperature: indication.
12. Space humidity set point - indication and adjustment.
13. Space humidity: indication and alarm.

3.11 CONTROL SEQUENCES: PAH-7

A. The system is a single zone variable air volume system. The air handling unit contains a variable speed supply, DX cooling coil, hydronic pre-heat coil, duct-mounted reheat coil, filters, and bipolar ionization air purification, as well as other components.

B. The unit shall be controlled by the BMS and shall be indexed to the occupied and unoccupied settings at the fully adjustable programmed times. Provide optimal start/stop programming.

C. Provide a temperature/humidity sensor with adjustable set points. The minimum and maximum set points shall be set through the BMS.

D. Freeze Protection: Provide a freeze stat, with manual reset, serpentined across the leaving air side of the heating coil and provide programming per the following sequence if the leaving air temperature falls below 35 deg. F. (adjustable):

1. Signal an alarm on the operator workstation.
2. Close the outdoor air dampers and open the return air damper.
3. Fully open the heating coil control valve.
4. Stop the fan.

E. Provide control wiring between the unit starter and a relay furnished by the electrical contractor to allow for fan(s) shut down when the fire alarm system activates. If activated close all outdoor air dampers.

F. In unoccupied modes provide controls to monitor the temperature in the mixed air section of the air handling unit. When the outdoor air temperature is below 35 deg. F. (adjustable) and the temperature in the mixed air section falls below 35 deg. open the heating coil control valve to maintain a temperature of 40 Deg. F (adjustable) in the unit section.

G. Provide fully modulating heating valves that are to fail in the open position. Control valves on the duct mounted reheat coils shall fail in the last position. Outdoor air dampers and relief vent dampers are to fail in the closed position with return dampers failing in the open position.

H. Provide a transducer to monitor and record pressure drop across the MERV 13 filters in the air-handling unit. An alarm will be activated at the BMS workstation if the actual filter pressure drop exceeds the dirty filter pressure drop established by the TAB Contractor.

I. Unoccupied heating cycle:

1. The air handling unit fan will be off. Outdoor air damper will be closed and the return air damper open.
2. When the space temperature falls below the unoccupied set point temperature of 60 deg. F. (adjustable) start the supply fan at full speed and open the preheat coil control valve to provide a 95 deg. F. leaving air temperature.
3. The outside air damper will remain closed. The return air damper shall remain fully open. When setback temperature has been restored, reverse this sequence.

J. Unoccupied cooling cycle: Two modes of operation shall be available. One mode is to have no cooling with all fans off and the outside air damper closed. The second choice is for a higher space cooling set point, which is described as follows:

1. The supply fan will be off, the outdoor air damper closed and the return air damper open.
2. When the space temperature rises above the unoccupied set point of 80 deg. F. (adjustable) start the supply fan at low speed and energize the DX cooling to supply a 54 deg. F. leaving air temperature. If required to maintain space temperature, slowly increase the fan speed, and

simultaneously increase the DX cooling to maintain a 54 deg. F. (adjustable) leaving air temperature. When the unoccupied space temperature has been restored, reverse the above sequence.

3. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor space, allow the unit to operate in an economizer mode. Start the supply fan at low speed and open the outdoor air damper to provide a 54 deg. F. (adjustable) leaving air temperature. If required to maintain space temperature, increase the supply fan speed, and simultaneously modulate open the outdoor air damper to maintain a 54 deg. F. leaving air temperature. The unit's barometric relief section will function to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable). The DX cooling will not function when the system is in an economizer mode.

K. Occupied heating cycle:

1. Warm-up: provide optimal start through the BMS to index the respective zone to the occupied status. At this time the unit will operate in the same mode as the unoccupied heating cycle. When the space temperature reaches the occupied set point the unit will operate in the occupied cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating from low to high speed to maintain the space temperature. Modulate the preheat coil control valve in unison with the supply fan to maintain a leaving air temperature of 95 deg. F. (adjustable).

L. Occupied cooling cycle:

1. Cool-down: provide optimal start through the BMS to index the respective zone to the occupied status. At this time, the unit will operate in the same mode as the unoccupied cooling cycle. When the space temperature reaches the occupied set point the unit will operate in the occupied cooling cycle.
2. During the occupied cycle the supply fan shall run continuously, modulating from low to high speed to maintain space temperature. Modulate the DX cooling in unison with the supply fan to maintain a 54 deg. F. (adjustable) leaving air temperature. The exhaust fan will modulate to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.g. Coordinate the locations of the space pressure sensor and the referenced sensor with the TABC.
3. Provide controls for economizer cooling. If the enthalpy of the outdoor air is less than the enthalpy of the respective indoor space, allow the unit to operate in an economizer mode. Start the supply fan at low speed and open the outdoor air damper to provide a 54 deg. F. (adjustable) leaving air temperature. If required to maintain space temperature, increase the supply fan speed, and simultaneously modulate open the outdoor air damper to maintain a 54 deg. F. leaving air temperature. The unit's barometric relief section will function to maintain a set building differential pressure with relationship to the atmosphere of +0.02" w.c. (adjustable). The DX cooling will not function when the system is in an economizer mode.

M. Dehumidification: At any time the space humidity is above 60% RH, run the supply fan at cooling airflow, open the cooling coil control valve to provide a 54 deg. F. (adjustable) leaving air temperature and modulate open the duct-mounted reheat coil control valve to maintain the space temperature set point. When the space humidity level falls below 55% RH, reverse the sequence. Dehumidification shall be available during unoccupied cycles with the outdoor air damper closed.

N. The BMS shall monitor, record, and display the following monitoring points on a custom graphic at the operator work station:

1. System status (Occupied / Unoccupied): indication and adjustment.
2. Supply fan status: indication, adjustment, and alarm.
3. Supply fan speed: indication and alarm.
4. Smoke detector status: indication and alarm.
5. Preheat coil control valve position: indication and adjustment.

6. Cooling coil control valve position: indication and adjustment.
7. Reheat coil control valve position: indication and adjustment.
8. Supply air temperature: indication and adjustment.
9. Return air temperature: indication.
10. Mixed air temperature: indication
11. Outdoor air c.f.m.: indication.
12. Freezestat status: indication and alarm.
13. Building pressurization: indication and adjustment.
14. Space temperature set point: indication and adjustment.
15. Space temperature: indication and alarm.
16. Space humidity set point: indication, adjustment.
17. Space humidity level: indication and alarm.
18. Bipolar Ionization generator status: indication.

3.12 CONTROL SEQUENCES: FC-1

A. All fan coil units shall be controlled by the BMS. The respective unit(s) shall be indexed to occupied and unoccupied settings at the programmed times. Provide optimal start/stop programming.

B. Provide a space thermostat / sensor and humidistat with adjustable set points. The minimum and maximum heating / cooling and humidity set points shall be set at the operator work station.

C. Freeze Protection: Provide a freeze stat, with manual reset, serpentined across the leaving air side of the cooling coil and provide programming per the following sequence if the leaving air temperature falls below 35 Degrees F (adjustable):

1. Signal an alarm on the operator workstation.
2. Close the outdoor air dampers and open the return air damper.
3. Fully open the heating coil control valve.
4. Stop the fan.

D. Provide fully modulating heating control valves that are to fail in the open position. Provide fully modulating chilled water control valves to fail in the last position. Outdoor air dampers and any relief vent dampers are to fail in the closed position with return dampers failing in the open position.

E. Provide an interlock with the condensate overflow sensor, located in the condensate drain pan at all horizontal units, to detect an increased condensate level due to a clogged drain pan. When an overflow condition is detected stop the supply fan and alarm the BMS.

F. Unoccupied Heating:

1. The outside air damper will be closed. The supply fan will be off. When the space temperature falls below the unoccupied fully adjustable set point, cycle the supply fan and open the heating coil control valve to satisfy the unoccupied temperature. When the unoccupied space temperature has been restored, reverse the sequence.

G. Unoccupied Cooling:

1. The outside air damper will be closed. The supply fan will be off. When the space temperature falls above the unoccupied fully adjustable set point, cycle the supply fan and open the cooling coil control valve to satisfy the unoccupied temperature. When the unoccupied space temperature has been restored, reverse the sequence.

H. Occupied Heating

1. Warm-up: provide optimal start through the BMS to index the respective zone to the occupied status and initiate morning warm-up. At this time, the unit will operate in the same mode as the unoccupied heating cycle. When the space temperature reaches the occupied set point the unit will operate in the occupied heating cycle.
2. During the occupied cycle the supply fan shall run continuously, the outdoor air damper will open to allow the scheduled amount of outdoor ventilation air. Modulate the heating coil control valve to maintain the space temperature.

I. Occupied Cooling:

1. Cool-down: provide optimal start through the BMS to index the respective zone to the occupied status and initiate morning cool -down. At this time, the unit will operate in the same mode as the unoccupied cooling cycle. When the space temperature reaches the occupied set point the unit will operate in the occupied cooling cycle.
2. During the occupied cycle the supply fan shall run continuously, the outdoor air damper will open to allow the scheduled amount of outdoor ventilation air. Modulate the cooling coil control valve to maintain the space temperature.

J. Dehumidification: At any time the space humidity is above 60% RH, run the supply fan at cooling airflow, open the cooling coil control valve to provide a 54 deg. F. (adjustable) leaving air temperature and modulate open the duct-mounted reheat coil control valve to maintain the space temperature set point. When the space humidity level falls below 55% RH, reverse the sequence. Dehumidification shall be available during unoccupied cycles with the outdoor air damper closed.

K. The BMS shall monitor, record, and display the following points on a custom graphic at the operator workstation:

1. System status: indication and adjustment.
2. Supply fan status: indication, adjustment, and alarm.
3. Heating coil control valve position: indication.
4. Cooling coil control valve position: indication.
5. Supply air temperature: indication.
6. Freezestat status: indication and alarm.
7. Condensate level sensor: alarm.
8. Space temperature set point: indication and adjustment.
9. Space temperature: indication.
10. Space humidity set point: indication and adjustment.
11. Space humidity: indication.

3.13 CONTROL SEQUENCES: HVAC FANS

A. Refer to the drawings for notes to indicate fans that are to be controlled by the BMS.

B. Provide controls for exhaust fans noted as "Time of Day Schedule" to allow the fan(s) to operate during the occupied cycle of the respective area. De-energize the fan(s) during the unoccupied cycle.

C. Where fans are noted to have a manual switch, provide an interlock to allow the fan(s) to operate during the occupied cycle of the respective area. De-energize the fan(s) during the unoccupied cycle.

D. Refer to the contract drawings for exhaust fans that are to be operated with an interlock to other equipment. Where so indicated, provide the required interlock and controls. Provide programming to prevent fan operation when the area is in an unoccupied mode.

E. Where noted as "Reverse Acting T'stat", provide a reverse acting thermostat in the space to energize the fan when the space temperature is above the set point. De-energize the fan when the space temperature is below set point. If required, provide motorized dampers as well as the required interlock with the fan and damper(s).

F. Where the drawings indicate a motor operated damper (MOD) is required, provide the damper, and control the damper to open when the fan is on and closed when the fan is off.

G. Refer to the drawings for interlocks and sequence information relating to the operation SF-1

H. The BMS shall monitor, record, and display the following points on a custom graphic at the operator workstation:

1. Status for all fans: indication and adjustment.
2. Occupied and unoccupied scheduling: indication and adjustment.

3.14 CONTROL SEQUENCES: FAN POWERED VARIABLE AIR VOLUME TERMINAL UNITS (FPV)

A. The units shall be controlled by the BMS. The respective unit(s) shall be indexed to occupied and unoccupied settings at the programmed times.

B. Provide a thermostat with adjustable set points for all fan powered variable air volume units. Refer to individual air handling unit sequence to determine which units require humidity sensors. The minimum and maximum space set points shall be set through the BMS.

C. Provide a modulating control valve for the hydronic heating coil that is provided with the variable air volume unit. Refer to the drawings for the required valve configurations. Valves are to fail in the last position.

D. Unoccupied heating: the primary air damper is closed. When the space temperature falls below the unoccupied set point, start the unit fan and open the heating coil control valve to satisfy the set point.

E. Unoccupied cooling: when the air handling unit energizes and the space temperature is above the unoccupied set point, open the primary air damper to the minimum c.f.m. position. If necessary, gradually open the primary air damper to maintain the unoccupied space temperature. Reverse the sequence when the space temperature is above the unoccupied set point.

F. Occupied: Before indexing each unit to occupied, start the vav fan with the fan operating continuously. When the space temperature is above the thermostat / sensor setting modulate open the primary air damper to allow the full cooling c.f.m. As the space temperature is satisfied gradually close the primary air damper to the minimum cooling c.f.m. position. When the space temperature is below the thermostat/sensor setting, the primary air damper is to be in the heating c.f.m. position. Modulate the heating coil control valve to control the space temperature.

G. Dehumidification: When the associated air handling unit is in dehumidification mode, provide the following sequence:

1. The VAV fan is on.
2. Open the primary air damper to allow the full cooling c.f.m.
3. Modulate the heating coil control valve to maintain the space temperature.
4. Reverse the sequence when the humidity level falls below the set point.

H. Occupancy Control: Provide wiring and all required controls to allow all vav boxes to enter a stand-by mode when indicated to do so by the room occupancy sensor. The occupancy sensor will be provided by others. When in the stand-by mode the fan will be off and the air inlet valve will be closed. If the room temperature falls more than 4 deg. F. (adjustable) below the normal room occupied heating temperature start the supply fan, and open the heating coil control valve to heat the space. If the room temperature rises more than 4 deg. F. (adjustable) above the normal room occupied cooling temperature start the supply fan an open the vav box inlet valve to cool the space.

I. The BMS shall monitor, record, and display the following monitoring points on a custom graphic at the operator workstation:

1. Room set point: indication and adjustment.
2. Room temperature: indication.
3. Room humidity level (where required): indication.
4. Primary air c.f.m.: indication.
5. Leaving air temperature: indication.

3.15 CONTROL SEQUENCES: SHUT-OFF VARIABLE AIR VOLUME TERMINAL UNITS (SOV)

A. The units shall be controlled by the BMS. The respective unit(s) shall be indexed to occupied and unoccupied settings at the programmed times.

B. Provide a thermostat with adjustable set points for all fan powered variable air volume units. Refer to individual air handling unit sequence to determine which units require humidity sensors. The minimum and maximum space set points shall be set through the BMS.

C. Provide a modulating control valve for the hydronic heating coil that is provided with the variable air volume unit. Refer to the drawings for the required valve configurations. Valves are to fail in the last position.

D. Unoccupied heating: the primary air valve is closed. When the associated air handling unit energizes and the space temperature is below the unoccupied set point, open the primary air damper to the minimum position and open the heating coil control valve to maintain the unoccupied space temperature. Reverse the sequence when the space temperature is above the unoccupied set point.

E. Unoccupied cooling: When the associated air handling unit energizes and the space temperature is above the unoccupied set point, open the primary air damper to the minimum c.f.m. position. If necessary, gradually open the primary air damper to maintain the unoccupied space temperature. Reverse the sequence when the space temperature is above the unoccupied set point.

F. Occupied: When the space temperature is above the room thermostat/sensor set point modulate open the primary air damper to allow the full cooling c.f.m. As the space temperature is satisfied gradually close the primary air damper to the minimum c.f.m. position. When the space temperature is below the thermostat/sensor setting, the primary air damper is to be in the heating c.f.m. position. Modulate the heating coil control valve to control the space temperature.

G. Dehumidification: When the associated air handling unit is in dehumidification mode, provide the following sequence:

1. Open the primary air damper to allow the full cooling c.f.m.
2. Modulate the heating coil control valve to maintain the space temperature.
3. Reverse the sequence when the humidity level falls below the set point.

H. Occupancy Control: Provide wiring and all required controls to allow all vav boxes to enter a stand-by mode when indicated to do so by the room occupancy sensor. The occupancy sensor will be provided by others. When in the stand-by mode the fan will be off and the air inlet valve will be closed. If the room temperature falls more than 4 deg. F. (adjustable) below the normal room occupied heating temperature start the supply fan, and open the heating coil control valve to heat the space. If the room temperature rises more than 4 deg. F. (adjustable) above the normal room occupied cooling temperature start the supply fan an open the vav box inlet valve to cool the space.

I. The BMS shall monitor, record, and display the following monitoring points on a custom graphic at the operator workstation:

1. Room set point: indication and adjustment.
2. Room temperature: indication.
3. Room humidity level (where required): indication.
4. Primary air c.f.m.: indication.
5. Leaving air temperature: indication.

3.16 CONTROL SEQUENCES: TERMINAL HEATING UNITS

A. All new terminal units and terminal units that are to remain shall be controlled by the BMS. Refer to the contract drawings for locations of existing terminal units. The respective unit(s) shall be indexed to occupied and unoccupied settings at the programmed times.

B. Provide a space thermostat/sensor with adjustable set points. The minimum and maximum heating and cooling set points shall be set at the operator work station.

C. Provide a two-position control valve for all terminal units. Refer to the drawings for the required valve configurations. Valves are to fail in the last position unless the unit has a connection to an outside air duct in which case the valve is to fail open.

D. Hydronic Baseboard / Finned Tube Control: Provide a thermostat/sensor to maintain occupied and unoccupied space temperature by opening the two-position heating control valve.

E. Hydronic Unit Heater Control: Provide thermostat/sensor to maintain the occupied and unoccupied space temperature by opening the two-position control valve and cycling the fan motor.

F. Cabinet Heater Control: Provide thermostat/sensor to maintain the occupied and unoccupied space temperature by opening the two-position control valve and cycling the fan motor.

G. The BMS shall monitor, record, and display the following monitoring points on a custom graphic at the operator workstation:

1. Status: indication and adjustment.
2. Room temperature set point: indication.
3. Room temperature: indication.

3.17 CONTROL SEQUENCES: RELIEF VENTS

A. Where indicated on the drawings relief vents are to be provided with motor operated dampers that are to fail closed.

B. Roof vents used for reducing building pressure are to modulate open based on an increase in building pressure during an occupied cycle of the respective system and are to be closed when the system is in an unoccupied mode unless the system is in an economizer cycle.

C. Relief vents that are connected to the discharge of an exhaust or relief fan are to be open when the respective fan is in an occupied mode and closed when the system is in an unoccupied mode.

3.18 CONTROL SEQUENCES: KITCHEN VENTILATION SYSTEMS (KVS-1 and KEF-1)

A. Provide control wiring between the unit starter and a relay furnished by this contractor to allow for fan(s) shut down when the fire alarm system activates. If activated close all outdoor air dampers.

B. The unit shall have the following safety controls: duct smoke detector located in the supply mains shall signal an alarm, interrupt power to the supply fan only, and close outside air dampers when products of combustion are sensed.

C. The ventilation equipment will be provided with controls to energize the system when the associated process equipment is energized and shall run continuously until the process equipment is de-energized. When the outside air temperature is 65 deg. F. (adjustable) or lower, a supply duct temperature sensor shall modulate the gas valve to the heating section to maintain a constant discharge temperature of 65 deg. F. (adjustable).

D. The BMS shall monitor, record, and display the following monitoring points on a custom graphic at the operator work station:

1. System status (on/off): indication.
2. Gas furnace status: indication.
3. Gas furnace leaving air temperature: indication.
4. Exhaust fan status: indication.

3.19 CONTROL SEQUENCES: DISHWASHER MAKEUP AIR

A. All associated dampers and control valves shall be controlled by the BMS. Interlock dishwasher operation with the existing roof mounted gravity intake ventilator and hot water heating coil where indicated on the drawings.

B. Freeze Protection: Provide a temperature sensor at the leaving side of the hot water heating coil and provide programming per the following sequence if the leaving air temperature falls below 40 Degrees F (adjustable):

1. Signal an alarm on the operator workstation.
2. Close the outdoor air damper.
3. Fully open the heating coil control valve.

C. Provide fully modulating heating control valve that fails in the open position. Provide 2-position outdoor air damper that fails in the closed position.

D. When dishwasher is energized, open motor operated damper associate with the existing gravity ventilator. Modulate heating coil control valve on associated hot water heating coil to maintain a discharge air temperature equal to the current room setpoint. Provide discharge air temperature adjustable setpoint to allow a control offset in relationship to the room setpoint.

E. The BMS shall monitor, record, and display the following points on a custom graphic at the operator workstation:

1. System status: indication and adjustment.
2. Heating coil control valve position: indication.
3. Oudoor air damper position: indication and adjustment.
4. Supply air temperature: indication.
5. Freezestat status: indication and alarm.
6. Space temperature set point: indication and adjustment.
7. Space temperature: indication.

3.20 CONTROL SEQUENCES: MISCELLEANOUS POINTS

A. The BMS shall monitor, record, and display the following points on a custom graphic at the operator work station:

1. Outdoor air temperature: indication.
2. Outdoor air humidity: indication.
3. Temperature monitoring of three (3) data rooms. Provide independent room sensor to monitor and display room temperatures. Provide a high temperature alarm in all rooms with the temperature set point as directed by the owner.
4. Monitor temperature in the walk-in refrigerator and freezer. Provide alarms when temperatures are above the adjustable set point.

3.21 CONTROL SEQUENCES: LIGHTING CONTROL

A. The exterior lighting shall be controlled via BMS system relay panels as specified. Each individual relay shall be individually programmed. The BMS graphical interface shall provide a different zone for each relay. The programs shall span the entire year allow for automatic on/off functionality, as well as override control from wall stations.

B. One (1) low voltage station shall be provided near the main normal panel to provide override control to turn the lights ‘on’ for a period of two (2) hours. The station shall be clearly labeled on the face plate. Field verify exact location in field prior to install.

C. In order to provide control of the exterior lighting based on dusk and dawn, an exterior photoelectric cell shall be provided on the northern exposure of the building. It shall be mounted at such a location that it is easily accessible from the roof, and the location shall be identified on the graphic floorplan of the BMS.

D. All areas that are controlled shall be graphically identified on a graphic floorplan in the BMS. A clear indication as to whether the lights are on or off shall be indicated on the graphic floorplan.

E. The following is an initial sequence of operation for the lighting system to follow. The owner reserves the right to request two (2) adjustments to this sequence within one (1) year after substantial completion at no additional cost.

1. Exterior Lighting:

a. Exterior lighting shall be controlled as follows:

1) Photocell on / off at 11:00pm (time to be verified with owner)
2) On at 5:00am – Photocell off (time to be verified with owner)

b. Exterior building mounted lighting, 1/3 of the area lighting and flag lights shall operate from dusk to dawn. Where fixtures are dimmable, they shall operate at 100% during the “on” time period, and at a reduced light output, as directed by the owner, during the “off” time period.

c. Coordinate exact lighting zones and lighting schedules with the owner.

END OF SECTION 23 09 05