SECTION 23 09 93 SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes points to be connected to DDC control system and sequence of operation for HVAC systems.

B. Related Sections:

1. Section 23 09 23 - Direct-Digital Control System for HVAC: For equipment, devices, system components, and software to implement sequences of operation.

2. All sections related to products requiring control and monitoring.

1.02 SUBMITTALS

A. Division 01 - Submittal Procedures: Submittal procedures.

B. Shop Drawings: Indicate mechanical system controlled and control system components.

1. Label with settings, adjustable range of control and limits. Submit written description of control sequence.

2. Submit flow diagrams for each control system, graphically depicting control logic.

3. Submit draft copies of graphic displays indicating mechanical system components, control system components, and controlled function status and value.

4. Coordinate submittals with information requested in Section 23 09 23.

1.03 CLOSEOUT SUBMITTALS

A. Division 01 - Execution and Closeout Requirements: Closeout procedures.

B. Project Record Documents: Record actual locations of components and setpoints of controls, including changes to sequences made after submission of shop drawings.

PART 2 – PRODUCTS - NOT USED

PART 3 - EXECUTION

3.01 POINTS TO BE CONNECTED TO DDC SYSTEM

A. Chilled Water System:

1. Start/Stop and running status for each chilled water pump.

2. Chilled water supply and return temperatures and flow rate from the plant entering each building.

3. Chilled water flow Chilled water pump status.

4. Status of each VFD and pressure differential control.

5. Differential pressure and differential pressure valve position.

6. Expansion tank pressures.

7. Chilled water supply and return temperatures and flow rate from the process chiller.

8. General alarm from process chiller.

9. Full communications with process chiller. Provide all gateways/software and hardware interfaces as required.

B. Heating System:

1. Start/Stop and running status for hot water pump.

2. Hot water supply and return temperatures from each system (preheat hot water and finned tube hot water)

3. Hot water flow to each system.

4. Calculate load for each system.

5. Status of each VFD and pressure differential control.

6. Differential pressure and differential pressure control valve position for each system.

7. Expansion tank pressures.

8. Steam flow for each building and steam pressure at entrance to building including steam flow to the existing ASB Building, 'G' Wing and Adler Center.

9. Steam control valve position

10. Steam condensate pump ON/OFF status and failure alarm.

11. Steam flow and totalization.

C. Air Handling Units:

1. Refer to Sequences of Operations.

D. Air Conditioning Units and Supplemental Cooling Units:

1. Start/ Stop and running Status.

2. Room temperature setpoint and actual temperature.

3. Common alarm.

E. All Pumps and fans:

1. Start/Stop and running Status.

2. Interlock with respective system.

3. Alarm failure on start/stop.

4. Full communication with variable speed drive.

F. VAV Boxes:

1. Space Temperature.

2. Flow Rate.

3. Damper position and valve position (if applicable).

G. High Temperature Alarms in the following rooms (through independent sensor):

1. Telecom Rooms/Data Closets (Typical of 4).

2. Main Electric Room.

3. EMR Room.

4. NMR Room.

5. IR Room.

6. Laser Rooms.

7. X-ray Rooms.

8. Physics Images Lab.

9. Each animal holding, surgery, research and preparation room (Typical of 8).

10. Physics Optics Lab.

11. Modern Physics Lab.

H. Miscellaneous HVAC Points:

1. Outdoor air temperature and relative humidity.

2. Variable Frequency Drives - General Fault.

3. Heat Tracing System Fault.

4. Humidifier General Fault.

5. Heat recovery system supply and return water temperature in and out of heat exchanger (each side).

6. Heat recovery pump on/off status.

7. Steam condensate return pump failure alarm.

I. Miscellaneous Plumbing Points:

1. Domestic hot water heaters high temperature and pressure alarms.

2. Domestic water service low pressure alarm.

3. Sump Pumps and ejectors High Level Alarms. In addition, provide alarm output to Campus security system.

4. Sump pumps and ejectors status.

5. Gas meter - consumption (cubic feet).

6. Water meter - consumption (Gallons).

7. Elevator Pumps - High level alarm. In addition, provide alarm output to Campus security system.

J. Miscellaneous Electrical Points:

1. Emergency generator run-time.

2. Generator Status.

3. Generator Pre-Alarm.

4. Generator failure Alarm.

5. Fire Alarm Status.

6. Building Electrical Consumption (KWH).

7. Primary Transformer High Temperature.

8. Instantaneous kW Demand.

9. Full graphical interface with lighting control system.

10. Connection to power metering system provided in Division 26.

3.02 HEATING SYSTEM

A. Heating Hot Water Distribution:

1. Heating hot water is provided via the use of three steam to low temperature hot water converters; one is dedicated for the Finned Tube Radiation and Reheat system and one is dedicated for the preheat system, and the third one is a common standby heat exchanger.

2. Low temperature hot water discharge temperature shall be controlled via the use of one 1/3 and one 2/3 flow steam control valves to maintain variable discharge water in accordance with the following:

a. Hot water for finned tube radiation/reheat shall be scheduled with outside air temperature by modulating the steam control valve control valves, in inverse proportion to schedule below:

OAT	=	0°F	HWS	=	200°F
OAT	=	60°F	HWS	=	140°F

b. Hot water for preheat system shall maintain fixed discharge temperature as indicated in contract schedules.

3. When the heat exchanger is active, its water isolation manual valve shall be open. The manual isolation valve shall be closed when the heat exchanger is inactive.

4. The heat exchanger water isolation control valve and steam control valves shall open when either the pre-heat or reheat hot water pumps connected to respective systems are operational.

5. Steam 1/3 and 2/3 control valves shall be modulated in sequence to maintain supply water temperature. 1/3 value shall be fully open prior to modulating 2/3 valve open. Valves shall close in reverse when temperature is satisfied.

6. Standby heat exchanger operation shall be manual to serve respective loop.

B. FTR/Terminal Reheat Hot Water Distribution:

1. The FTR/reheat hot water distribution system is served by one 100% pump and a common standby pump.

2. In the event the lead hot water pump sustains an outage, an alarm shall be annunciated at the BMS. The common standby pump shall be activated manually and the respective manual valve shall be opened/closed to serve the loop.

3. The control panel status of each VSD pump shall be monitored by the BMS system. The common trouble or malfunction alarm shall be monitored by the BMS.

4. Normal operation is to run one VSD pump.

5. Differential pressure of the hot water system is monitored and controlled by a differential pressure transmitter.

    a. The DDC software controller shall modulate the variable speed drives to maintain a (adj.) pressure differential as defined by the TAB contractor to maintain flow to the most remote terminal coil.

    b. Hot water differential pressure controller varies its output signal and modulates the VSD to meet and the required differential pressure.

    c. When the running pump reaches its minimum RPM, the differential pressure bypass valve shall be modulated open to maintain an adjustable pressure differential.

6. The FTR pump shall be commanded to start when there is a call for heating from any individual space. Pump shall be commanded to stop when there is no call for heating for 30 minutes (adj.).

C. Pre-Heat Hot Water Distribution:

1. The Pre-heat hot water distribution system is served by one pump and a common standby pump.

2. In the event the lead water pump sustains an outage, an alarm shall be annunciated at the BMS. The common standby pump shall be activated manually and the respective manual valves shall be opened/closed to serve the piping loop.

3. The hot water pumps can be started from the lead/lag software selector or manually from the workstation, or from the starter.

4. The control panel status of each pump shall be monitored by the DDC system. The pump failure common trouble or malfunction alarm shall be monitored by the DDC system.

5. Normal operation is to run one VSD pump.

6. Differential pressure of the hot water system is monitored and controlled by a differential pressure transmitter.

    a. The DDC software controller shall modulate the variable speed drives to maintain a (adj.) pressure differential as defined by the TAB contractor to maintain flow to the most remote terminal coil.

    b. Hot water differential pressure controller varies its output signal and modulates the VSD to meet and the required differential pressure.

    c. When the running pump reaches its minimum RPM, the differential pressure bypass valve shall be modulated open to maintain an adjustable pressure differential.

7. The preheat pump shall be commanded to start when the outdoor air temperature falls below 55°F (adj.) and there is a call for heating. Pump shall be commanded to stop when there is no call for heating for 30 minutes (adj.).

8. On a rise in outdoor temperature above 60°F (adj.), the pump shall shut down.

9. Pre-heat system shall have glycol make-up tank/pump system which shall energize and inject glycol in the system based upon an adjustable low system pressure setting.

3.03 SECONDARY CHILLED WATER PUPMING SYSTEM

A. Secondary Chilled Water Distribution:

1. The chilled water distribution system is served by two pumps; one running pump and a standby pump.

2. In the event the lead water pump fails, an alarm shall be annunciated at the BMS and the standby pump shall come on line automatically through the BMS signal.

3. The chilled water pumps can be started from the lead/lag software selector or manually from the workstation, or from the starter.

4. The control panel status of each pump shall be monitored by the BMS. The common trouble or malfunction alarm shall be monitored by the BMS.

5. Normal operation is to run one VSD pump.

6. Differential pressure of the chilled water system is monitored and controlled by a differential pressure transmitter.

    a. The DDC software controller shall modulate the variable speed drives to maintain a (adj.) pressure differential as defined by the TAB contractor to maintain flow to the most remote terminal coil.

b. Chilled water differential pressure controller varies its output signal and modulates the VSD to meet and the required differential pressure.

c. When the running pump reaches its minimum RPM, the differential pressure bypass valve shall be modulated open to maintain an adjustable pressure differential.

7. The lead pump shall be commanded to start when the outdoor air temperature rises above 50°F (adj.) and there is a call for cooling and chilled water is available from the central plant as indicated by entering chilled water temperature of less than 55°F. Pump shall be commanded to stop when there is no call for cooling for 30 minutes (adj.).

8. On a drop in outdoor temperature below 50°F (adj.), the running pump shall shut down.

3.04 100% OUTSIDE AIR VARIABLE VOLUME AIR HANDLING UNITS FOR LABORATORY (AHU 1, AHU 2)

A. Safeties:

1. Automatic Operation: When alarmed, smoke detectors or signal from the fire alarm system shall stop the respective supply air fan. When smoke condition is cleared and detectors are reset, the system shall resume normal operation.

2. Freezestat Operation: The freezestat (low temperature) detectors, one for each preheat coil located downstream of the coils, shall be set for activation at 35°F. Upon detecting freeze conditions, supply fan shall stop and outside air dampers shall close.

To prevent nuisance fan shutdowns, provide a time delay of 0-30 seconds (adjustable) before activation occurs. Once the fan has been shut down, manual reset, through a push button located at the DDC Panel, will be required to restart the fan.

3. Static Pressure Operation: The supply fan shall shut down upon a high discharge pressure or low suction pressure condition and shall stop the associated return fan through software interlock. Once the fan has been shut down, manual reset, through a push button located at the DDC Panel, will be required to restart the fan.

B. Unit Off:

1. Upon unit shutdown on schedule or a command from BMS or other shut down command, the fan motors shall be de-energized, the air handling unit's outside air dampers shall close; the chilled water valve shall close.

2. System OFF: Whenever the air handling system is off, the outdoor air damper will close; the cooling coil control valve shall close and associated fire/smoke damper shall close.

3. The preheat coil control valves will remain under control of the preheat coil discharge temperature sensors, to maintain a setpoint of 39°F (adjustable) during cold weather.

C. System Start Up:

1. The supply air fan of the air handling unit shall be started per operation schedule or on a command from BMS and enable the outdoor air dampers. The supply air fan shall start with its respective variable speed drive at minimum flow position, through a time delay after outside air damper is proven open by the end switch, and remain at minimum flow for 60 seconds (adjustable). The outside air damper shall be opened 100% and the fire/smoke dampers shall open.

D. Unit On:

1. Static Pressure Control:

   a. Static pressure sensor, located at the most remote VAV box, shall modulate the supply fan variable speed drive to maintain the static pressure setpoint. The numerical value of the setpoint shall be based on supplying rated air flow to the most remote VAV box. The system shall have supply air dynamic static pressure reset capabilities to reduce fan energy. The system shall confirm VAV box damper positions and adjust the static pressure setpoint to maintain proper air flow at all VAV boxes and reduce excessive throttling at VAV boxes.

   b. Units shall be in operation 24 hours, 7 days.

E. Seasonal Mode:

1. There are two (2) seasonal modes of operation: "Heating Season" and "Cooling Season". System operation shall be automatically indexed to "Cooling Season" when the program verifies that chilled water from the Central Plant is less than 55°F, as sensed by the primary chilled water temperature sensor located in the MER, and the outside air temperature is greater than 61°F, then the controls will be indexed to cooling. Below 56°F ambient, outside air temperature program indexes the system to "Heating Season". These modes may also be manually commanded at the console keyboard. Below 56°F, the cooling coil control valves for the air handling units shall be commanded to the closed position.

2. The air handling unit system's air discharge temperature will be maintained at a given setpoint for the heating and cooling season:

   Heating Season – 60°F (adjustable)
   Cooling Season – 55°F (adjustable)

F. Heating:

1. Each air handling unit serving the laboratory shall have glycol water heat recovery coil (matched with the lab exhaust system), to temper the outside air. When the heat recovery coil cannot maintain the required supply air temperature, the preheat coil control valve shall be modulated open to maintain the supply air temperature setpoint.

2. To maintain discharge air temperature setpoint in the "Heating Season", the discharge air temperature sensor will, through a three-mode (P + I + D), direct acting fan discharge temperature software controller, modulate the preheat coil control valves in sequence with heat recovery coil to maintain discharge air temperature setpoint. This sequence shall be reversed as

weather becomes warmer; when the outdoor weather temperature becomes warm enough for the "Cooling Season", the cooling coil valve will be modulated to maintain discharge air temperature setpoint. When the cooling coil control valve is open, the heating coil control valve shall be closed and heat recovery system shall be off and vice versa.

3. Low Limit Control for Preheat Coils: If the discharge air controller does not maintain a leaving air temperature from the preheat coils above 39°F (adjustable), the local preheat controllers will, through a three-mode (P + I + D) direct acting temperature controller, override the discharge air controller and modulate valves to maintain the temperature of the air leaving the preheat coils at 39°F, adjustable. Anti-reset windup will be provided to prevent controller overshoot by suppressing integral control until the control point is within the controller's proportional band. Provide one low limit controller per each preheat coil.

4. Preheat coils in each unit shall utilize glycol solution for freeze protection.

G. Cooling:

1. To maintain discharge air temperature in the cooling season, the discharge air temperature sensor will, through a three-mode (P + I + D), direct acting temperature software controller, modulate the chilled water valve to maintain the discharge temperature setpoint of 55°F (adjustable).

2. Chilled water from the Central Plant is available for the cooling season only; during the heating season, the chilled water coils of the air handlers may be protected by preheat coil during periods of sub-freezing weather.

H. Heat Recovery System:

1. When outdoor air temperature is below 50°F, the runaround heat recovery loop system shall be activated. The heat recovery system circulating pump for the respective system shall start and heat shall be recovered from the exhaust air stream. When outdoor air is above 50°F, bypass dampers around heat recovery coil at air handling unit shall be open.

2. When outdoor air temperature is below 40°F, the heat recovery hot water heat exchanger two-way valve shall modulate to maintain a minimum 38°F entering glycol temperature to exhaust air coil to prevent frost buildup.

3. The lead/lag heat recovery pump shall be selected at the BMS or through a local controller. If the lead pump fails, an alarm shall be annunciated at the BMS and the lag pump shall be commanded to start.

I. Zone Control Temperature Reset:

1. DDC system shall poll damper position of VAV boxes to determine if supply air discharge setpoint can be reset up in 1°F increments(with a maximum supply air temperature of 60 degree F) to allow for energy savings. Reverse shall occur when supply air temperature cannot provide adequate cooling.

J. Indication:

1. System Monitoring: The DDC system will monitor: temperature transmitters, heat recovery discharge temperature, preheat air temperature, supply air temperature, outside air temperature; chilled water supply temperature; chilled water return temperature, static pressure transmitter, supply air flow

rates, fan status, air flow measuring stations (supply air), VAV box CFMs, Fire Alarm Status (shutdown), Freezestat Status, Dirty Filter Alarm, High and Low Pressure Alarm and humidifier on/off status, valve position and damper positions.

K. Alarms:

1. The following alarms will be displayed at the DDC System Console:

	ATC Item	*Alarm Setpoint (adj.)*
1)	Freezestats	35°F
2)	Dirty Air Filters	1.25” w.g.
3)	Supply Air Fan Failure	1” w.g.
4)	Winter Discharge Air	62°F; 52°F High/Low
5)	Preheat Coil	58°F; 50°F High/Low
6)	Static Pressure (varies per system)	1.5” w.g.
7)	Safety Shutdown	
8)	Smoke Shutdown	
9)	CFM Differential	
10)	VFD Fault Indication	

3.05 100% OUTSIDE AIR VARIABLE VOLUME AIR HANDLING UNITS FOR ANIMAL LAB (AHU 3-1, AHU 3-2)

A. The Animal Room air conditioning system comprises two (2) air handling units including one operating unit and a standby unit. The operating unit shall be selected at the BMS. The operating unit shall be alternated on a weekly basis. One unit shall be in operation on a 24-hour, 7-day basis.

B. These units shall receive chilled water from the Campus central chiller plant.

C. Each unit shall be provided with a chilled water cooling coil. A supplemental cooling DX coil with a matching condensing unit will be provided for off-season cooling when the central plant chilled water is not available.

D. Safeties:

1. Automatic Operation: When alarmed, smoke detectors or a signal from the fire alarm system shall stop the respective supply air fan. When smoke condition is cleared and detectors are reset, the system shall resume its normal operation.

2. Freezestat Operation: The freezestat (low temperature) detectors, one for each preheat coil located downstream of the coils, shall be set for activation at 35°F. Upon detecting freeze conditions, supply fan shall stop and outside air dampers shall close.

   To prevent nuisance fan shutdowns, provide a time delay of 0-30 seconds (adjustable) before activation occurs. Once the fan has been shut down, manual reset, through a push button located at the DDC Panel, will be required to restart the fan.

3. Static Pressure Operation: The supply fan shall shut down upon a high discharge pressure or low suction pressure condition and shall stop the respective supply fan. Once the fan has been shut down, manual reset, through a push button located at the DDC Panel, will be required to restart them.

4. When the operating unit is off upon safety, an alarm shall be annunciated at BMS. The standby unit shall be commanded to start at the BMS by the operator.

E. Unit Off:

1. Upon unit shutdown on schedule or a command from BMS or other shut down command, the fan motors shall be de-energized, the air handling unit's outside air dampers shall close; the chilled water valve shall close and the fire smoke dampers in the duct shall close.

2. System OFF: Whenever the air handling system is off, the outdoor air damper shall close; the cooling coil control valve shall close and associated fire/smoke damper shall close.

3. The preheat coil control valves shall remain under control of the preheat coil discharge temperature sensors, to maintain a setpoint of 39°F (adjustable) during cold weather.

F. System Start Up:

1. The operating air handling unit supply air fan shall be started per operation schedule or on a command from BMS and enable the respective outdoor air damper and respective discharge damper. The supply air fans shall start after a time delay, after outside air damper and discharge air damper is proven open through the end switch, with their respective variable speed drives at minimum flow position and remain at minimum flow for sixty seconds (adjustable). Fire-smoke dampers shall be opened.

G. Unit On:

1. Static Pressure Control:

a. Static pressure sensor, located at the most remote VAV box, shall modulate the supply fan variable speed drive to maintain the static pressure setpoint. The numerical value of the setpoint is based on supplying rated air flow to the most remote VAV box. The system shall have supply air dynamic static pressure reset capabilities to reduce fan energy. The system shall confirm VAV box damper positions and adjust the static pressure setpoint to maintain proper air flow at all VAV boxes and reduce excessive throttling at VAV boxes.

b. The unit shall be in operation 24 hours, 7 days.

H. Seasonal Mode:

1. There are two (2) seasonal modes of operation: "Heating Season" and "Cooling Season". System operation shall be automatically indexed to "Cooling Season" when the program verifies that chilled water from the Central Plant is less than 55°F, as sensed by the primary chilled water temperature sensor located in the MER, and the outside air temperature

(sensed by a common main outside temperature sensor) is greater than 61°F, then the controls will be indexed to cooling. Below 56°F, outside air temperature program indexes the system to "Heating Season". These modes may also be manually commanded at the console keyboard. Below 56°F, the cooling coil control valves for the air handling units shall be commanded to the closed position.

2. The air handling unit system's air discharge temperature will be maintained at a given setpoint for the heating and cooling season:

Heating Season	–	60°F (adjustable)
Cooling Season	–	55°F (adjustable)

I. Heating:

1. To maintain discharge air temperature setpoint in the "Heating Season", the discharge air temperature sensor shall, through a three-mode (P + I + D), direct acting fan discharge temperature software controller, modulate the preheat coil control valves to maintain discharge air temperature setpoint. This sequence shall be reversed as weather becomes warmer; when the outdoor weather temperature becomes warm enough for the "Cooling Season", the cooling coil valve will be modulated to maintain discharge air temperature setpoint.

2. Low Limit Control for Preheat Coils: If the discharge air controller does not maintain a leaving air temperature from the preheat coils above 39°F (adjustable), the local preheat controllers will, through a three-mode (P + I + D) direct acting temperature controller, override the discharge air controller and modulate valves to maintain the temperature of the air leaving the preheat coils at 39°F, adjustable. Anti-reset windup will be provided to prevent controller overshoot by suppressing integral control until the control point is within the controller's proportional band. There will be one low limit controller per each preheat coil:

3. Preheat coils in each unit shall utilize glycol solution for freeze protection.

J. Cooling:

1. To maintain discharge air temperature in the cooling season, the discharge air temperature sensor shall, through a three-mode (P + I + D) direct acting temperature software controller, modulate the chilled water valve to maintain the discharge temperature setpoint of 55°F (adjustable).

2. When chilled water from the central plant is not available, as sensed by the temperature sensor in the chilled water main (CHW temperature above 50°F), the DX cooling shall be energized to maintain the supply air temperature setpoint.

K. Zone Control Temperature Reset:

1. DDC system shall poll damper position of VAV boxes to determine if supply air discharge setpoint can be reset up in 1°F increments (with a maximum supply air temperature of 60 degree F) to allow for energy savings. Reverse shall occur when supply air temperature cannot provide adequate cooling.

L. Humidifier:

1. Steam generating electric humidifier shall be activated when the average space humidity in the spaces served by the air handling unit falls below its setpoint. Humidifier shall be modulated and cycled based to maintain space humidifier setpoint.

2. High limit humidistat in main supply duct shall prevent humidistat operation when humidity in the supply duct exceeds 85% RH.

3. Water fill control valve shall maintain water level in humidifier.

4. Automatic drain flush cycle shall be activated as required by the humidifier integral controls.

M. Indication:

1. System Monitoring: The BMS system will monitor: temperature transmitters, preheat air temperature, supply air temperature, supply air humidity % RH, high humidity alarm, outside air temperature; chilled water supply temperature; chilled water return temperature, static pressure transmitter, supply air flow rates, fan status, air flow measuring stations (supply air), VAV box CFMs, Fire Alarm Status (shutdown), Freezestat Status, Dirty Filter Alarm, High and Low Pressure Alarm and humidifier on/off status, valve positions, damper positions, DX system condensing units and on/off status.

N. Alarms:

1. The following alarms will be displayed at the DDC System Console:

	ATC Item	*Alarm Setpoint (adj.)*
1)	Freezestats	35°F
2)	Dirty Air Filters	1.25” w.g.
3)	Supply Air Fan Failure	1” w.g.
4)	Winter Discharge Air	62°F; 52°F High/Low
5)	Preheat Coil	58°F; 50°F High/Low
6)	Static Pressure (varies per system)	1.5” w.g.
7)	Safety Shutdown	
8)	Smoke Shutdown	
9)	CFM Differential	
10)	VFD Fault Indication	
11)	High Supply Air Temperature	65°F and above
12)	High Space Temperature (each space)	80°F and above
13)	Supply Air Flow Rate	
14)	Low space humidity in each space served by the AHU	20%
15)	High space humidity in each space served by the AHU	60%

3.06 VARIABLE VOLUME AIR HANDLING UNITS WITH RETURN AIR (AHU-4, AHU-5 and AHU-1A)

A. Safeties:

1. Automatic Operation: When alarmed, smoke detectors or signal from the fire alarm system shall stop the respective supply air and (through software interlock) the return air fan. When smoke condition is cleared and detectors are reset, the system resumes normal operation.

2. Freezestat Operation: The freezestat (low temperature) detectors, one for each preheat coil, are located downstream of the coils and shall be set for activation at 35°F. Upon detecting freeze conditions, supply fan shall stop and outside air dampers shall close.

   To prevent nuisance fan shutdowns, provide a time delay of 0-30 seconds (adjustable) before activation occurs. Once the fan has been shut down, manual reset, through a push button located at the DDC Panel, will be required to restart them.

3. Static Pressure Operation: The supply fan shall shut down upon a high discharge pressure or low suction pressure condition and shall stop the associated return fan through software interlock. The return fan shall shut down upon a low suction pressure condition and shall stop the associated supply fan through software interlock. Once the fan has been shut down, manual reset, through a push button located at the DDC Panel, will be required to restart them.

B. Unit Off:

1. Upon unit shutdown on schedule or a command from BMS or other shut down command, the fan motor shall be de-energized, the air handling unit's minimum and maximum outside air damper and spill air damper shall close; the return air damper shall open; the chilled water valve shall close.

2. System OFF: Whenever the air handling system is off, the outdoor air damper and spill air damper shall be close; the return air damper shall open; the cooling coil control valve shall close and associated fire/smoke damper shall close.

3. The preheat coil control valves shall remain under control of the preheat coil discharge temperature sensors, to maintain a setpoint of 39°F (adjustable) during cold weather.

C. System Start Up:

1. The supply air fan of the air handling unit shall be started per operation schedule or on a command from BMS and enable the outdoor air (minimum, and maximum), spill air and return air dampers. The return air fan shall be started through software interlock. The supply and return air fans shall start with their respective variable speed drives at minimum flow position and remain at minimum flow for sixty seconds (adjustable). The minimum outside air damper will open 100%. The minimum spill air damper shall open as required to meet minimum outside air intake and the maximum spill air damper shall remain closed and remain in this position unless overridden by economizer control or by requirement for 100% outside air. The associated fire/smoke dampers shall open.

2. During system start up in winter, the economizer cycle will be locked out for five minutes (adjustable) to prevent unstable operation of the maximum outside air damper.

D. Unit On:

1. Static Pressure Control:

a. Static pressure sensor, located at the most remote VAV box, shall modulate the supply fan variable speed drive to maintain the static pressure setpoint. The numerical value of the setpoint shall be based on supplying rated air flow to the most remote VAV box. The system shall have supply air dynamic static pressure reset capabilities to reduce fan energy. The system shall confirm VAV box damper positions and adjust the static pressure setpoint to maintain proper air flow at all VAV boxes and reduce excessive throttling at VAV boxes.

b. To maintain the building under a positive pressure, the supply air fan's air flow shall be tracked by a volumetric tracking system, which shall maintain a constant air flow differential between the supply and return air fans. Air measuring devices in the supply air and return air fans will, through differential pressure transmitters, modulate the return fan's variable speed drive to maintain the differential air flow.

c. A flow measuring device in the minimum outdoor air duct shall modulate the minimum outdoor air damper, return air and spill air dampers to ensure the minimum outdoor air intake.

2. Unoccupied Mode:

a. In the unoccupied mode, the Outdoor air minimum and outdoor air maximum damper shall be closed. Spill Air damper shall be closed and return air damper shall be open.

b. In unoccupied mode, occupant may start AHU by pressing the night override switch located on the room thermostat. Upon activation, unit shall start and operate in occupied mode for 30 minutes minimum.

3. Occupied Mode:

a. During minimum outside air mode (non-economizer), spill air damper shall be in its open position. Return air damper shall be open.

b. The minimum outside damper shall be open and the maximum outside air damper shall be closed except when system is in economizer operation.

c. Demand Control Ventilation:

1) During startup, the unit shall provide the minimum outdoor air flow rate as indicated in Contract Schedules for a minimum of 5 minutes. After the 5-minute startup, the following shall occur:

a) Carbon dioxide sensors shall be provided in all high occupancy spaces and in main return ducts at each floor.

b) If all of the space and duct sensor carbon dioxide levels (note: Systems have more than one carbon dioxide sensor) are less than 500 ppm above outdoor levels, and less than 900 ppm overall, for a minimum of 5 minutes, the outdoor air flow rate shall be reduced to 50% of minimum outdoor flow rate indicated in Contract Schedules, via modulation of minimum outdoor air damper.

c) If any of the space or duct carbon dioxide levels are greater than 500 ppm above outdoors levels or greater than 900 ppm overall, the outdoor air flow rate shall be increased to the minimum outdoor air flow rates indicated in Contract Schedules.

d) If any of the space or duct carbon dioxide levels are greater than 500 ppm above outdoor levels or greater than 900 ppm or greater than 5 minutes, after contract minimum outdoor air has been provided, the maximum outdoor air damper shall modulate open and indicate an alarm at the BMS.

e) Upon a reduction in carbon dioxide levels below prescribed levels indicated above, for a minimum of 5 minutes, the maximum air damper shall close.

E. Seasonal Mode:

1. There are two seasonal modes of operation: "Heating Season" and "Cooling Season". System operation shall be automatically indexed to "Cooling Season" when program verifies that chilled water from the Central Plant is less than 55°F, as sensed by the primary chilled water temperature sensor located in the MER, and the outside air temperature (sensed by a main outside temperature sensor) is greater than 61°F, then the controls will be indexed to cooling. When the outdoor air temperature is between 55°F and 60°F, 100% outside air will be used for cooling; below 56°F, outside air temperature program indexes system to "Heating Season". These modes may also be manually commanded at the console keyboard. Below 56°F, the cooling coil control valves for the air handling units shall be commanded to the closed position.

2. The air handling unit system's air discharge temperature is maintained at a given setpoint for the heating and cooling season:

   Heating Season – 60°F (adjustable)
   Cooling Season – 55°F (adjustable)

F. Heating:

1. To maintain discharge air temperature setpoint in the "Heating Season", the discharge air temperature sensor will, through a three-mode (P + I + D), direct acting fan discharge temperature software controller, modulate in sequence, the automatic dampers for economizer control-maximum outside air damper, maximum and minimum spill air dampers and return air damper,

and finally the preheat coil control valves in sequence as the weather becomes colder. This sequence is reversed as weather becomes warmer; when the outdoor weather temperature becomes warm enough for the "Cooling Season", the cooling coil valve will be modulated to maintain discharge air temperature setpoint.

2. Low Limit Control for Preheat Coils: If the discharge air controller does not maintain a leaving air temperature from the preheat coils above 39°F (adjustable), the local preheat controllers will, through a three-mode (P + I + D) direct acting temperature controller, override the discharge air controller and modulate valves to maintain the temperature of the air leaving the preheat coils at 39°F, adjustable. Anti-reset windup will be provided to prevent controller overshoot by suppressing integral control until the control point is within the controller's proportional band. Provide one (1) low limit controller per each preheat coil. Preheat coils in each unit shall utilize glycol solution for freeze protection.

G. Cooling:

1. To maintain discharge air temperature in the cooling season, the discharge air temperature sensor shall, through a three mode (P + I + D), direct acting temperature software controller, modulate the chilled water valve to maintain the discharge temperature setpoint of 55°F (adjustable). When outside air temperature is between 50 degree F and 60 degree F , 100% outside air will be used to take advantage of lower total heat of outside air versus return air. Above 60°F the minimum outside air damper will be open, the maximum outside air damper will be closed, the return air damper open and the maximum spill air damper stay closed and the minimum spill air damper opened to ensure minimum outside air intake.

2. Chilled water from the Central Plant is available for the cooling season only; during the heating season, the chilled water coils of the air handlers may be protected by preheat coil during periods of sub-freezing weather.

H. Economizer – 100% Outside Air for Cooling:

1. The economizer cycle, set for 100% outside air, will be operative whenever the outside air temperature is between 50°F and 60°F. (adj.). Below 50°F the air handler will be in heating mode. Above 61°F the air handler will be in cooling mode. For the economizer cycle at 100% outside air, the minimum outside air damper will be open, the maximum outside air damper will be open, the return air damper will be closed and the maximum spill air damper will stay open. The discharge air temperature sensor will, through a three-mode (P + I + D), direct acting fan discharge temperature software controller and modulate the chilled water valve to maintain the setpoint during integrated economizer cycle. For outside temperature below 50°F, the controller shall modulate the maximum outside air, maximum spill air and return air dampers to maintain setpoint during economizer cycle in the heating mode.

I. Zone Control Temperature Reset:

1. DDC system shall poll damper position of VAV boxes to determine if supply air discharge setpoint can be reset up in 1°F increments(with a maximum supply air temperature of 63 degree F) to allow for energy savings. Reverse shall occur when supply air temperature cannot provide adequate cooling.

J. Morning Warm-up and Cool Down:

1. In the warm-up mode, the preheat hot water control valve shall be indexed full open, the spill air dampers and outdoor air dampers shall be closed and the return air damper shall be open. The VAV box dampers shall be commanded to full open position and the hot water reheat valves shall be commanded open.

2. In morning cool-down mode, the cooling coil control valve shall be indexed full open, the spill air dampers and outdoor air dampers shall be closed and the return air damper shall be open. The VAV box dampers shall be commanded to full open position and the hot water reheat valves shall be commanded closed.

K. Night Setback:

1. Under a winter night setback mode, space sensors for each FTR or VAV perimeter zone shall operate the control valve to modulate flow of water to maintain space set-back temperature. When space temperature falls below 55°F, the AHU shall start with no outdoor air capability, and the preheat coil shall open to maintain space temperature setpoint where VAV boxes without heat coil are used.

2. Under a summer night setback mode, when any space temperature rises above 80°F (adj.), the AHU shall start with no outdoor air or capability, and the cooling coil shall open to maintain space temperature.

L. Indication:

1. System Monitoring: The DDC system will monitor: temperature transmitters, mixed air temperature, preheat air temperature, supply air temperature, return air temperature, outside air temperature; chilled water supply temperature; chilled water return temperature, static pressure transmitter, supply and return air flow rates, outdoor air flow rate, fan status, air flow measuring stations (supply, return and outside air), VAV box CFMs, Fire Alarm Status (shutdown), Freezestat Status, Dirty Filter Alarm, High and Low Pressure Alarm, valve positions and damper positions.

M. Alarms:

The following alarms will be displayed at the DDC System Console:

	ATC Item	*Alarm Setpoint (adj.)*
1)	Freezestats	35°F
2)	Dirty Air Filters	1.25” w.g.
3)	Supply Air Fan Failure	1” w.g.
4)	Return Air Fan Failure	1” w.g.
5)	Winter Discharge Air	62°F; 52°F High/Low
6)	Preheat Coil	58°F; 50°F High/Low
7)	Static Pressure (varies per system)	1.5” w.g.
8)	Safety Shutdown	
9)	Smoke Shutdown	
10)	CFM Differential	
11)	VFD Fault Indication	
12)	Carbon Dioxide Level	1000 ppm

	ATC Item	Alarm Setpoint (adj.)
13)	Outdoor Air Flow Rate	<50% of minimum outdoor flow rate as indicated in Contract Schedule
14)	Supply Air Flow Rate	
15)	Return Air Flow Rate	

3.07 NON-LABORATORY VAV BOXES

A. Controls for Variable Air Volume Terminal Units - Cooling Only:

1. The VAV terminal box controller monitors the space temperature sensor and velocity sensor. The controller shall modulate the supply air damper to maintain the desired room temperature. If the space temperature is below its adjustable 75° setpoint, the primary air damper shall modulate to its minimum position. As the space temperature rises above its setpoint, the primary damper shall modulate open.

2. The supply air volume shall be modulated between by its minimum and maximum supply air volume settings.

3. When the air handling system is in warm-up mode or cool-down mode, the primary air damper shall be fully open.

4. The damper motor and controls shall be furnished by the ATC contractor, for installation by the VAV box manufacturer at its factory. Controls shall be electronic DDC.

5. All VAV terminal units shall be addressable from the standalone controllers.

6. During normal occupied periods, if there is no occupancy as sensed by room occupancy sensor (no occupancy for greater than 25 minutes), VAV box shall close fully and setpoint shall be allowed to “float” between 70°F and 78°F. Upon sensing occupancy, unit shall revert to normal operation.

B. Controls for Non-Lab Variable Air Volume Terminal Units - Hot Water Reheat with Minimum Primary Air:

1. The VAV terminal box controller monitors the space temperature sensor and velocity sensor. The controller shall modulate the supply air damper and reheat control valve and finned tube control valves in the space served by the VAV box in sequence to maintain the desired room temperature. (Note: Some VAV boxes control multiple finned tube radiation control valves. Refer to Contract Drawings.) If the space temperature is below its adjustable 75° setpoint, the primary air damper shall modulate to its minimum position. On further drop in space temperature below the setpoint, finned tube control valves and VAV box reheat control valves shall be modulated in sequence to maintain space temperature and the primary air damper shall be in its minimum position. As the space temperature rises above its setpoint, the hot water control valves shall modulate closed and the primary damper shall modulate open. In general, the fintube radiator control valve shall be modulated open prior to opening the VAV reheat control valve.

2. The supply air volume shall be limited by its minimum and maximum supply air volume settings.

3. When the air handling system is in warm-up mode, the primary air damper and hot water control valve shall be fully open.

4. The damper motor and controls shall be furnished by the ATC contractor, for installation by the VAV box manufacturer at its factory.

5. All VAV terminal units shall be addressable from the standalone controllers.

6. During normal occupied periods, if there is no occupancy as sensed by room occupancy sensor (no occupancy for greater than 25 minutes), VAV box shall close fully and setpoint shall be allowed to “float” between 70°F and 78°F. Upon sensing occupancy, unit shall revert to normal operation.

C. Fan-Powered VAV Box:

1. Fan-powered box shall be pressure independent and shall deliver constant volume of air at all times.

2. In cooling mode, primary air shall be modulated between minimum and maximum to maintain space temperature set at the thermostat. As the cooling load decreases, control shall throttle primary air and terminal box shall make up the difference by taking more return air from the plenum to deliver constant air flow.

3. In heating mode, primary air damper shall be modulated to maintain space thermostat setpoint. Once the primary air damper reaches its minimum setpoint, the hot water heating coil control valve shall be opened and modulated to maintain space thermostat setpoint.

4. Fan powered box fan shall operate continuously in the heating or cooling mode.

5. When the primary air is shut down (air handling unit is off); box fan shall use return air from the ceiling plenum and modulate the heating coil control valve to maintain minimum space temperature (65°F, adjustable) at the space thermostat.

3.08 LABORATORY CONTROL SYSTEMS (LACS)

A. VAV Fume Hood Face Velocity Control:

1. Furnish and install a UL 916 listed individual VAV fume hood controller for each VAV fume hood which shall maintain the required average face velocity at the setpoint independently of the sash position. Documentation verifying the UL 916 Listing for the fume hood controller shall be included in the submittal. Furnish sash sensors for installation by fume hood vendor at their factory on each fume hood to indicate the position of all fume hood sashes to the respective fume hood controller. Provide all field wiring and devices as required for a complete and operational system. Sash sensors shall provide an input signal to the fume hood controller that is linearly proportional to within one half inch of the actual sash position. All sash sensors shall be highly corrosion resistant and allow easy removal of a fume hood's sashes for cleaning. Sash sensor operational life shall allow a minimum of 1 million full sash travel cycles.

2. The fume hood face velocity control process shall maintain the average fume hood face velocity at the desired setpoint using a proportional, integral and

derivative (PID) closed loop control algorithm. The fume hood face velocity control process shall be as follows:

a. The fume hood controller shall continually determine the fume hood's total open area by monitoring the fume hood sash position(s) by the sash sensor(s) as well as taking account of any fume hood fixed open areas and the bypass opening(s).

b. The fume hood controller shall calculate the required fume hood exhaust airflow necessary to maintain the average face velocity setpoint over the total open area. The controller shall continuously perform the above exhaust airflow control calculations ten times per second to ensure detection of and a maximum of 1 second response to any change in sash position.

c. The fume hood controller shall control the fume hood exhaust airflow at the rate necessary to maintain the average face velocity setpoint. The fume hood controller shall ensure that the required fume hood exhaust to maintain the average face velocity setpoint is always maintained independently of any variations in exhaust system static pressure or any laboratory room conditions such as the ventilation airflow or room static pressure that could otherwise affect the fume hood exhaust airflow.

d. The fume hood face velocity control process shall accommodate the required fume hood maximum to minimum exhaust airflow rate. The fume hood controller shall always maintain the required minimum fume hood exhaust airflow recommended by laboratory safety standards whenever the total fume hood open area requires less than the calculated fume hood exhaust airflow necessary to maintain the average face velocity setpoint. The fume hood controller shall also be capable of limiting the maximum fume hood exhaust airflow regardless of the extent of the sash opening.

e. The fume hood controller shall also interface to an Operator Display Panel (ODP) on the front of the fume hood. The ODP shall provide a continuous digital display of average fume hood face velocity whenever the fume hood sash open area requires more than the minimum fume hood exhaust airflow. The fume hood face velocity display shall be the true average face velocity as calculated by the fume hood controller based upon actual measured fume hood exhaust airflow and the total fume hood total open area.

f. The ODP shall also include separate colored pilot lights that shall illuminate to indicate fume hood operational status as:

    1) Green for proper face velocity.

    2) Yellow for marginal face velocity.

    3) Red for face velocity alarm conditions.

    The ODP shall also sound an audible alarm device in response to face velocity alarm conditions and the ODP digital display shall change to "LOW FACE VELOCITY" or "HIGH FACE VELOCITY" appropriate to the alarm condition. A SILENCE pushbutton on the ODP shall allow the user to silence the audible alarm which shall then remain silent until a subsequent face velocity alarm occurs.

g. The ODP shall also provide an EMERGENCY PURGE pushbutton which shall enable a user to increase fume hood exhaust airflow to the maximum amount for a designated period of time as required by laboratory safety standards. After the designated time has expired the fume hood exhaust shall automatically reset to a lower level to prevent excessive demand on the exhaust system. The emergency purge mode of operation shall also be able to be cancelled at any time by depressing the emergency purge button a second time. The ODP shall sound its audible alarm device whenever the emergency purge mode of operation is activated. The silence pushbutton on the ODP shall also allow the user to silence the audible alarm which shall then remain silent until either the emergency purge operational mode is again activated or a face velocity alarm occurs.

h. The ODP shall also provide an audible sash open alert feature that can be implemented to caution users whenever the fume hood sash opening exceeds a predetermined amount. The audible alert shall consist of one minute repeating cycles of a series of quick 'chirps' that continues until the sash opening is reduced to an allowable amount. In addition, failure of a fume hood sash sensor shall also be indicated as an alarm condition on the ODP.

3. All fume hood control and ODP display and operational parameters shall be established and be changeable only by authorized personnel using a portable operator's terminal. These operational parameters shall include:

   a. Fume hood average face velocity setpoint.

   b. Fume hood minimum & maximum exhaust airflow.

   c. Face velocity high and low alarm limits and associated alarm time delay to avoid transient alarms.

   d. Face velocity high and low warning limits.

   e. Emergency purge time periods and exhaust levels.

   f. Allowable maximum sash opening associated with the sash alert feature.

4. The portable operator’s terminal shall plug into the ODP as well as into the laboratory room controller through a communication port in each ODP and LRS. In addition, all laboratory fume hood and laboratory room control parameters along with all other facility control and monitoring functions shall be accessible to authorized personnel from designated terminals on the BMS control and monitoring network.

5. Momentary or extended losses of power shall not change or affect any VAV fume hood control setpoints, operational parameters or stored data. Upon resumption of power after a power failure, fume hood controllers shall resume full normal operation exactly as before the power failure and without any need for manual intervention. Upon a power failure or operational failure within the fume hood controller, the fume hood exhaust

air terminal shall be automatically positioned to the fully open (failsafe) position as required by laboratory safety standards.

B. Laboratory Room Controller (LRC):

1. For each laboratory, furnish and install a dedicated laboratory room controller to provide closed loop pressure independent control of all laboratory room ventilation and ambient requirements. The laboratory room controller shall continuously monitor the exhaust airflow values from each VAV fume hood in the room. In addition, the laboratory room controller shall continuously measure the room general exhaust airflow rate and room miscellaneous exhausts as applicable to individual laboratory rooms and as indicated in the laboratory room control schedule in the project plans.

2. LRC shall control and integrate the following major control function as detailed:

   a. Laboratory ventilation rate.

   b. Laboratory pressurization by tracking supply air, general exhaust and fume hood exhaust.

   c. Laboratory space temperature.

   d. Occupied/unoccupied ventilation changeover.

3. All laboratory room controllers shall include all inputs and control outputs necessary to perform the specified control sequences, perform all computations and tracking control functions. Each laboratory room controller shall operate as a standalone unit, performing its specified control responsibilities independently. All input point and control output point databases as well as the control programs shall be stored in non-volatile EEPROM, EPROM and PROM memory, or a minimum of 72-hour battery backup shall be provided.

4. Momentary or extended losses of power shall not change or affect any laboratory room controller setpoints or stored data. Upon resumption of power the controller shall resume full normal operation exactly as before without any need for manual intervention. Upon a power failure or operational failure within the controller, the air terminal shall automatically be positioned to the predetermined fully open or fully closed (failsafe) position as indicated on the air terminal schedules in the project plans.

5. All laboratory room controllers shall include the ability to accept and incorporate a dry contact closure input from an auxiliary source into the room control sequence for such purposes as occupied/unoccupied ventilation changeover, emergency mode sequences, etc.

6. All laboratory room controllers shall provide a general alarm output that may be used for auxiliary signaling or notification.

C. VAV Room Ventilation Rate Control with General Exhaust:

1. A. In addition to the VAV fume hood exhaust, the laboratory room controller (LRC) shall continuously measure the airflow rate of the other room exhaust provisions including the room general exhaust and all miscellaneous exhausts such as bench snorkels, etc. by an airflow measurement station.

2. The laboratory room controller (LRC) shall continuously totalize all room exhaust airflows as the total room exhaust airflow. The laboratory room controller shall continuously calculate the difference between the total room exhaust airflow and the room exhaust airflow required to maintain the room air ventilation rate (air change per hour) as listed in the laboratory room schedule in the plans. Whenever the total room exhaust airflow is less than the room exhaust airflow required to maintain the room minimum ventilation rate, the laboratory room controller shall increase the room general exhaust airflow until the total room exhaust airflow equals the required room exhaust airflow.

3. Whenever total room exhaust airflow is greater than the required room exhaust airflow, the laboratory room controller shall decrease the room general exhaust airflow until the total room exhaust airflow equals the required room exhaust airflow or the general exhaust airflow is reduced to its minimum value. The room minimum general exhaust minimum value shall be at least 12% of the maximum room general exhaust airflow rate to ensure that accurate general exhaust airflow measurement and control is continuously maintained.

4. The laboratory room controller shall control the room general exhaust airflow by a proportional, integral and derivative (PID) closed loop control algorithm. Each laboratory room controller shall be specifically designed for application to laboratory room ventilation and room ambient condition control. Each controller shall be a microprocessor-based, multi-tasking, real-time digital control processor. Control sequences shall be included as part of the factory supplied software. These sequences shall be able to be customized on site by adjusting parameters such as control loop algorithm gains, temperature setpoint, alarm limits, airflow differential setpoint, and pressurization mode. Control sequences that require a differential pressure switch to ensure adequate airflow exists through control devices such as venturi air valves shall also include provisions for manual and automatic zeroing of the differential pressure switch to ensure stable control and enable compensation for drift over time.

D. VAV Room Pressurization Control by Airflow Tracking:

1. The laboratory room controller(LRC) shall continuously totalize all room exhaust airflows including fume hood exhausts, miscellaneous exhausts such as bench snorkels and the room general exhaust, as applicable to individual rooms, as the total room exhaust airflow. The laboratory room controller shall also continuously measure the room supply airflow by means of an airflow sensor in the room supply air terminal(s).

2. The laboratory room controller shall continuously control the room supply airflow at value necessary to maintain the predetermined (adjustable) airflow tracking differential between the total room exhaust airflow and the room supply airflow as listed in the room airflow schedule on the project plans. For negatively pressurized rooms the room supply airflow shall always be maintained at a greater value than the total room exhaust airflow by the airflow tracking differential cfm (l/s). For positively pressurized rooms the room supply airflow shall always be maintained at a lower value than the total room exhaust airflow by the airflow tracking differential cfm (l/s).

3. The laboratory room controller shall ensure that the required supply airflow cfm (l/s) necessary to maintain the airflow tracking differential is always maintained by a proportional, integral and derivative (PID) closed loop control algorithm.

4. Review Division 23 Drawings for air flow and pressurization requirements.

E. VAV Room Temperature Control by Temperature Sensing - Single Supply Duct:

1. The laboratory room controller shall continuously measure the temperature in the room by means of the room temperature sensor. The laboratory room controller shall maintain the room temperature at its adjustable setpoint by initially modulating a normally closed, equal percentage, reheat valve and the normally open perimeter finned tube control valve (when the outdoor air temperature is below (60°F). Perimeter control valve shall be 1st stage on heat when outdoor air temperature is below 60°F. The room temperature control action shall utilize a proportional, integral and derivative (PID) closed loop control algorithm. The laboratory room temperature setpoint shall be established by authorized personnel through the plug-in, portable operator's terminal.

2. If room cooling needs to increase when the reheat valve is fully closed, the laboratory room controller shall increase both the room general exhaust airflow (when a general exhaust is present in the room) and the room supply airflow to maintain the room temperature as well as the airflow tracking differential at the setpoint.

3. If room cooling needs to subsequently decrease, the laboratory room controller shall decrease both the room general exhaust and the supply airflow while still maintaining the room temperature setpoint and the room minimum airflow and pressurization constraints.

4. If the room supply airflow is at its minimum value and a further reduction in room cooling is needed, both the room supply airflow and room general exhaust airflow (when present) shall be held constant and the reheat valve and perimeter finned tube control valve shall be modulated as required to maintain the room temperature setpoint.

F. VAV Room Temperature Control with Btu Compensation - Single Supply Duct:

1. The laboratory room controller shall continuously measure the temperature in the room by means of the room temperature sensor. The laboratory room controller shall also continuously measure the room supply air discharge temperature by means of a discharge air temperature sensor. The laboratory room controller shall maintain the room temperature at its adjustable setpoint by modulating a normally open, equal percentage reheat valve and the normally open perimeter finned tube control valve (when the outdoor air temperature is below (60°F). Perimeter control valve shall be 1st stage on heat when outdoor air temperature is below 60°F. In addition, when a general exhaust is present in the room the room temperature shall be maintained at its adjustable setpoint by varying the room supply airflow and general exhaust airflows.

2. If room cooling needs to increase while the reheat valve has been positioned to close off water flow through the reheat coil, the laboratory room controller shall increase both the room general exhaust and the supply airflow (when a general exhaust is present in the room) to maintain the room temperature as well as the airflow tracking differential at the setpoint.

3. If room cooling needs to subsequently decrease, the laboratory room controller shall decrease both the room general exhaust and the supply airflow as much as possible while still maintaining the room temperature setpoint and the room minimum airflow constraints. If the room ventilation

rate is at its minimum value and a further reduction in room cooling is needed, the room supply airflow shall be held constant and the reheat valve and finned tube control valve shall be modulated to meet the room temperature setpoint.

4. To minimize a potential room temperature swing away from the room temperature setpoint the laboratory room controller shall also incorporate BTU compensation temperature control. Btu compensation shall be based upon continuously calculating the room’s heating or cooling load in BTU’s per hour based upon the difference between the room temperature and the supply air discharge temperature and room supply airflow. Whenever a significant change in the room supply airflow suddenly occurs, the laboratory room controller shall utilize BTU compensation control action to quickly raise or lower the room supply air discharge temperature to maintain the room's previous BTU’s per hour cooling effect.

5. BTU compensation control action shall consist of immediately positioning the reheat valve to attain a new room supply air discharge temperature, which in combination with the new room supply airflow, shall maintain the room’s previous BTU per hour cooling effect. The room ambient temperature control with BTU compensation control action shall utilize a proportional, integral and derivative (PID) closed loop control algorithm.

G. VAV Room Ventilation Rate - Occupied/Unoccupied Mode Changeover:

1. The individual room ventilation control sequence shall include a provision for automatic and manual occupied/unoccupied room ventilation mode changeover.

2. The room occupied mode of ventilation control shall be in effect whenever scheduled room unoccupancy criteria (i.e., time of day, day of week, date, etc.) is not in effect and an input to the laboratory room controller intended to indicate unoccupancy is not present.

3. When in the occupied mode, the room ventilation rate and the room ambient parameters shall be controlled as indicated in the room ventilation schedule of the project plans.

4. The room unoccupied mode of ventilation control shall be in effect whenever scheduled room unoccupancy criteria (i.e., time of day, day of week, date, etc.) is in effect an input to the laboratory room controller intended to indicate unoccupancy is present. Additionally, room occupancy sensor indicates an unoccupied room during occupied periods, when no occupancy is sensed for greater than 30 minutes. Upon sensing occupancy, via sensor, room shall return to occupied ventilation rates.

5. When in the unoccupied mode of control, the room ventilation rate and the room ambient parameters shall be controlled as indicated in the room ventilation schedule in the project plans. When in the unoccupied mode of control, the room pressurization control sequence shall remain in effect and each VAV fume hood in the room shall continue to have its face velocity and minimum fume hood exhaust maintained as listed in the fume hood schedule in the project plans.

3.09 LABORATORY ROOM CONTROL PRIORITY (VAV OPERATION)

A. A control priority structure shall apply to all room ventilation and fume hood control functions to ensure that safety requirements are addressed in proper order to prevent a conflict in control operations or an inability of the ventilation system to fulfill its requirements. The room ventilation and fume hood control priority structure shall be as listed with the lowest numbered item (#1) having the first or highest operational priority and proceeding sequentially through the list with the highest numbered item having the lowest operational priority.

1. Fume Hood Face Velocity Control:

   a. Unless an emergency mode of control is in effect, all VAV fume hood controllers in the room shall be allowed to maintain their respective fume hood face velocity setpoints independent of the action of the laboratory room controller.

2. Room Ventilation Rate (Air Changes per Hour):

   a. Unless an emergency mode of control is in effect, laboratory rooms having a general exhaust shall maintain sufficient general exhaust airflow so that the total room exhaust airflow (fume hood exhausts plus miscellaneous room exhausts plus the room general exhaust) will provide the required minimum room ventilation rate (minimum of 4 air changes per hour).

3. Room Pressurization:

   A. Unless a fire emergency mode is in effect, the laboratory room controller shall maintain required room pressurization

4. Room Occupied/Unoccupied Ventilation Changeover:

   a. Unless an emergency mode is in effect, the laboratory room controller shall maintain the room's minimum ventilation rate and ambient conditions in accord with whether the room is in the occupied or unoccupied mode.

5. Room Ambient Conditions:

   a. Room ambient temperature and humidity shall always be maintained in accord with the room's occupied or unoccupied mode.

3.10 FUME HOOD AND ANIMAL LAB EXHAUST FAN CONTROL

A. Variable System Static Pressure – Multiple Variable Speed Operating Fans:

1. Laboratory fume hood exhaust system consists of two (2) sets of exhaust systems with three (3) fans each, of which two (2) fans shall run and one (1) fan shall be standby. Each laboratory exhaust system has a heat recovery unit with heat recovery coil, coil bypass damper and outside air bypass damper(s).

2. Animal Lab exhaust system consists of two (2) fans, of one (1) fan shall run and one (1) fan shall be standby.

3. Heat recovery coil bypass damper shall open when outdoor air temperature is above 45°F and shall close when outdoor temperature is below 40°F.

4. Exhaust system static pressure shall be measured at one or more exhaust system locations as designated on the plans. The exhaust system control sequence shall ensure that the static pressure level does not fall below

design setpoint at each designated measurement location. This value shall be reset pending determination of individual exhaust box valve position to reduce energy when exhaust demand is low. If the exhaust system static pressure at any designated measurement location falls below or exceeds the setpoint value for an amount of time that exceeds an adjustable alarm delay period, a static pressure alarm condition shall be initiated.

5. Whenever the static pressure at any designated static pressure measurement location becomes less than the setpoint, the outside air bypass damper opening shall be gradually reduced to lessen the amount of incoming bypass air and thus restore the exhaust system static pressure to the setpoint. Whenever the static pressure at all of the designated static pressure measurement locations becomes greater than the setpoint, the outside air bypass damper opening shall be gradually increased to increase the amount of incoming bypass air and thus lower the exhaust system static pressure until the setpoint value is reached at one of the designated measurement locations. The exhaust system bypass damper control sequence shall always be functional and the outside air bypass damper control action shall utilize a proportional, integral & derivative (PID) closed loop control algorithm.

6. Minimum exhaust fan speed shall always be sufficient to maintain a 3,000 feet per minute vertical stack discharge velocity as measured by velocity sensor in the discharge fan. Whenever the outside air bypass damper control sequence positions the outside air bypass damper to less than 10% open, the exhaust fan speed control sequence shall gradually increase fan speed until either maximum fan speed is attained or the outside air damper is open more than 10%. Whenever the outside air bypass damper control sequence positions the outside air bypass damper to more than 15% open, the exhaust fan speed control sequence shall gradually decrease the fan speed until either the outside air bypass damper opening needs to be reduced to less than 15% open or minimum fan speed to meet 3000 FPM discharge is attained. The exhaust fan speed control sequence shall initiate an increase in fan speed only when the outside air bypass damper is less than 10% open and shall initiate a decrease in fan speed only when the outside air bypass damper is more than 15% open; however, the minimum 3000 FPM outlet velocity shall always be achieved.

7. Whenever the assigned criteria (i.e. time of day, day of week, date, etc.) establishes that the facility has entered the occupancy period, the exhaust fan speed control sequence shall operate with a minimum of two exhaust fans running for each set of Laboratory exhaust systems. If two (2) fans are running at minimum exhaust fan speed and the bypass damper is more than 30% open, the exhaust fan staging sequence shall turn off one (1) fan and allow the exhaust fan speed control sequence to control the speed of the one (1) operating fan to maintain the bypass damper at less than a 30% opening. Whenever one (1) exhaust fan is running and its speed exceeds 130% of minimum fan speed (or 80% of maximum overall speed, whichever is less) to meet the 3000 FPM discharge requirement and the bypass damper is less than 20% open, a second fan shall be started and the exhaust fan speed control sequence shall uniformly control the speed of the operating fans up to the maximum allowable fan speed.

8. Whenever the assigned criteria (i.e. time of day, day of week, date, etc.) establishes that the facility has entered the unoccupancy period, the exhaust system speed control sequence shall attempt to maintain the bypass damper at a minimal opening with one (1) exhaust fan running. When the unoccupied period begins and two (2) fans are running and the bypass

damper is open more than 30%, the exhaust fan staging sequence shall turn off one fan and the exhaust fan speed control sequence shall continue to control the speed of the remaining operating fan to maintain the bypass damper at less than a 30% opening. If the bypass damper opening becomes less than 10%, the exhaust fan staging sequence shall revert to the occupied mode of control with multiple fans running until the bypass damper again opens to more than 20%.

9. Exhaust fan motors shall be equipped with a variable speed drive type motor controller with an integral provision for selecting local (manual) or remote (automatic) control. When local (manual) control is selected, the fan motor shall be under full local control regarding its on/off status as well as operational speed. When remote (automatic) control is selected, the fan motor shall be enabled for automatic on/off control in accord with the exhaust fan startup and exhaust fan shutdown sequences. Proof of fan operation shall be by means of an output from the variable speed motor controller or a motor current sensor that provides positive indication of the fan motor operating under fan load. When commanded to run, a lack of such proof of fan operation within an adjustable delay period shall initiate an exhaust fan failure alarm.

10. Each exhaust fan shall have a normally closed (N.C.) isolation damper prior to its inlet. The isolation damper shall be automatically closed when the respective fan is not running and shall isolate the fan from exhaust system fumes to prevent reverse exhaust air from flowing through the non-operating fan and also prevent service personnel from coming into contact with the exhaust air stream. The isolation damper shall be equipped with an end switch that shall close to indicate when the damper is fully open. The isolation dampers shall operate in conjunction with the exhaust fan startup and exhaust fan shutdown sequences.

11. Whenever a fan is started by a manual or automatic command, an automatic startup sequence shall ensure that reverse airflow does not initially occur through the non-operating fan. This startup sequence shall consist of first energizing the fan motor to a preset (adj.) speed and waiting until feedback is obtained from the motor controller indicating proof of fan operation. Upon receiving proof of fan operation, the fan inlet damper shall be commanded open and upon receiving indication that the damper has fully opened (via closure of the damper end switch), fan speed shall be increased as required to maintain the desired exhaust system airflow and negative static pressure setpoint. Fan start shall be staggered by one minute to prevent multiple fans from starting at once.

12. Whenever a fan is shutdown by a manual or automatic command, the control sequence shall ramp down the fan motor and after reaching the preset (adjustable) speed, the controller shall close fan’s inlet isolation damper. When the damper is fully closed, the fan shall be de-energized. Whenever the only operating fan is to be shutdown by a manual or automatic command, the exhaust fan control sequence shall ensure that the exhaust system is not subjected to a temporary or indefinite period of partial or total loss of airflow. This control sequence shall consist of first initiating a startup of a non operating (replacement) fan via the exhaust fan startup sequence. After the startup of the replacement fan has occurred, the exhaust fan control sequence shall de-energize the fan motor of the fan to be shut down and shall close fan’s inlet isolation damper after an appropriate delay period.

13. To equalize fan run time, the exhaust fan control sequence shall maintain an hour of accumulated run time tabulation for each exhaust fan. Whenever the exhaust fan control sequence needs to start an exhaust fan and fans are off, it shall start the exhaust fan with the lowest number of total operating hours. Whenever the exhaust fan control sequence needs to stop an exhaust fan and multiple fans are on, it shall shut down the exhaust fan with the highest number of total operating hours. Whenever a fan with the highest amount of run time is shut down, the control system shall assign that fan as the standby fan. Each individual fan's run time hours may be manually reset from an operator's terminal on the BMS. Running fan for animal exhaust system shall be rotated on a weekly basis.

14. Upon the occurrence of an exhaust fan failure alarm (which shall be indicated at the operator workstation), the standby exhaust fan shall be automatically commanded on in accord with the exhaust fan startup sequence. If two (2) exhaust fans are running and the exhaust system static pressure falls to a predetermined level below the setpoint for more than a specific period of time, or when an exhaust fan failure alarm occurs, the standby exhaust fan shall be automatically commanded on.

3.11 SUPPLEMENTAL AC UNITS (SPLIT SYSTEMS)

A. AC units shall run 24 x 7 days a week and shall be under the control of the AC unit controller.

B. Status of AC units shall be monitored at BMS.

C. General Alarm shall be monitored at BMS.

D. Provide separate room temperature sensor and controller to monitor room temperature for alarm.

E. Integral controls shall cycle condensing unit compressor and condenser fan to maintain cooling thermostat set point.

F. Provide leak detector and leak detector alarm panel for each system split AC unit.

3.12 FAN COIL UNITS

A. Fan Coil Units:

1. Each fan coil unit shall be provided with one local control panel controller. Provide all power and signal wiring to each device in the space.

2. The space thermostat shall control Fan Coil Units and associated Control Valves as specified herein:

a. Fan Coil Units shall be provided with manual low/medium/off fan speed switches which control operation of Fan Coil Unit fans.

b. Actuation of low voltage control valves for fan coil unit heating and cooling coil control valves shall be controlled by wall thermostat and local controller to maintain space temperatures.

3.13 RADIANT HEATING

A. Radiant heating system shall be enabled when outdoor air temperature is less than 50°F.

B. Upon a call for space heating from any space served by radiant heating system, the radiant heating supply and return isolation valves shall open and associated secondary radiant heat pump shall start, primary hot water control valve shall modulate to maintain 100°F (adj.) discharge water temperature. If there is no call for heating for a duration of 5 minutes (adjustable), the associated radiant pump shall stop and the associated isolation valves shall close.

C. Radiant heating shall be 1st stage of heat in the individual spaces. Upon a call for heat in any individual space, the associated radiant heating manifold valves shall modulate open. Primary hot water valve shall be modulated to ensure that the average slab temperature does not exceed 85°F (as sensed by four (4) slab temperature sensors). If after 5 minutes of operation, space temperature cannot be met, 2nd stage of heating (hot water reheat or fin-tube) shall be brought on-line. Upon meeting space temperature setpoint, the reverse shall occur.

3.14 DIFFERENTIAL PRESSURE CONTROLLERS

A. A differential pressure controller, pipe to sense differential pressure between supply and return lines, shall control a bypass water control valve to maintain an adjustable pressure differential between the supply and return lines. Provide differential pressure bypass control systems for each chilled water and hot water system.

3.15 TYPICAL EXHAUST FAN CONTROL

A. When the exhaust fan is off, its associated spill air damper or intake damper shall be closed. When the exhaust fan is on, its associated dampers shall open.

B. Start/stop programming of all such fans shall be programmable from the BMS.

C. For G wing first floor engineering physics shop provide a local switch to start the physics shop exhaust fan.

3.16 ELECTRICAL AND MECHANICAL EQUIPMENT ROOM VENTILATION

A. A room thermostat shall cycle the exhaust fan and supply fan/supply air damper on and off to maintain desired conditions or a rise in temperature above 85°F (adjustable) fan shall start. Exhaust fans serving Main Electrical Rooms shall be equipped with variable speed drives and shall vary their speed of the fan in response to space temperature. When the fan starts, the outside air intake and spill air dampers shall open. When the fan stops, the dampers shall close.

B. Adler Fan Room AC-2ME1: Fan shall operate continuously to maintain minimum -.1" w.g. pressure with respect to the corridor. Modulate fan speed via VFD.

C. Alarm shall be issued by BMS system when ventilation system fails or room temperature exceeds its setting.

3.17 UNIT HEATERS AND CABINET HEATERS

A. For each hydronic unit heater, a line voltage electric thermostat and aquastat shall start and stop the unit motor and engage heater to maintain an adjustable space temperature. An automatic control valve shall stop water flow through unit heater when motor is off.

B. For each hydronic cabinet heater, provide automatic summer shut-off valve, hot water control valve, thermostat and aquastat. Control valve shall modulate water flow as called for by the return air thermostat.

C. Electrical cabinet units shall be provided with return air thermostat to control the heating elements.

3.18 NIGHT SET-BACK MODE FOR ALL HVAC SYSTEMS

A. A space thermostat shall cycle supply and return fan of each unit to maintain thermostat's setting whenever the AC system is not running but the space temperature falls below 50°F. When running under this mode, the outside air dampers shall stay closed and reheat coils active. In spaces served by the finned tube radiator, maintain 50°F temperature for perimeter zone. A space temperature sensor shall start the hot water pump.

3.19 PUMPS

A. Provide manual selector switch for all pumps to enable selection of active pump wherever standby pumps are provided. All pumps shall have start/stop and status indication at the BMS.

3.20 VARIABLE FREQUENCY DRIVES (VFD)

A. VFD’s shall have four district modes of operation:

1. OFF – VFD and motor are off.
2. HAND – VFD output is manually controlled via speed selector input on drive.
3. AUTO – VFD output is controlled by BMS.
4. BYPASS – Drive Electronics are bypassed and unit acts as an across-the-line-starter operating at 100% speed. This allows for maintenance of drive while motor is still operating.

B. VFD’s shall have full communication capabilities with the BMS. Provide all interfaces, gateways, etc. as required for communications between the VFD’s and BMS.

3.21 GAS CYLINDER STORAGE SPACE

A. Provide gas detector in cylinder storage space to provide local alarm and alarm on BMS.

3.22 NMR ROOM

A. Provide oxygen sensor in NMR room to provide local visible and audible alarm when oxygen level in room falls below setpoint and alarm on BMS.

3.23 LEAK DETECTION AND ALARM PANEL

A. Provide drip pan below each split system AC unit with leak detector sensor.

B. Provide a local alarm panel with visible red pilot light and audible alarm with horn and silence switch. Provide metal and painted cabinet. Locate alarm panel in the vicinity of the units, adequately supported.

3.24 TOILET EXHAUST FANS

A. Toilet exhaust fans shall start and run per pre-program routine at BMS.

3.25 COOLING CONDENSATE PUMP

A. The integral float control shall activate and run the condensate pump to maintain water level in the reservoir.

3.26 ADLER LAB EXHAUST AND SUPPLY SYSTEM

A. Supply and exhaust systems shall be two-position controls for supply and exhaust terminal box. Supply and exhaust air flows shall be tracked for proper pressurization in lab.

B. When the Lab is occupied as sensed by the occupancy sensors or programmed in the occupied mode at BMS, bench top exhaust box and supply box(es) shall be indexed to its high flow setting as shown.

C. When the Lab is unoccupied as sensed by the occupancy sensor(s), branch top exhaust box and supply terminal box(es) shall be indexed to its low flow setting to save energy.

D. Exhaust Fan EF-6A serving the Lab bench top exhaust VFD speed spall ramp up and down to provide required exhaust based on static pressure in the exhaust duct as sensed by static pressure in the main exhaust duct for the system.

E. Exhaust Fan EF-7A exhausting mechanical room where Lab exhaust fan EF-6A is located shall be in operation at all times. Exhaust Fan EF-7A speed shall vary to maintain negative pressure in the mechanical room in relation to the adjoining corridor as sensed by sensors in the corridor and mechanical room.

3.27 G-WING BENCH TOP EXHAUST

A. Exhaust system terminal box for bench top exhaust shall be two position controls. Supply for the lab with bench top exhaust shall be variable volume to accommodate air for fume hood exhaust.

B. When the Lab is occupied, as sensed by the occupancy sensors or programmed as occupied at the BMS, the bench top exhaust box(es) shall be indexed to its high flow setting as shown.

C. When the Lab is unoccupied as sensed by the occupancy sensor(s), the bench top exhaust box(es) shall be indexed to its low flow setting as shown.

D. Supply box(es), bench top box(es) and fume hood box flows shall be tracked to provide required flow(s) as well as maintain proper pressurization in the Lab.

END OF SECTION