SECTION 230993 - SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. PROJECT DESCRIPTION –

This school has an existing BAS in place - the current control vendor on campus is ALS. All new controls shall extend off of and be capable of fully integrating with this existing BAS.

This project consists of work to replace existing rooftop units as described on drawings and schedule. New factory rooftop unit control sequencing needs to comply with the below sequences of operation. The points specified below shall be pulled from the new rooftop units into the existing BAS graphics. and will be verified during commissioning. The intent is to pull in all points on the existing graphics for a seamless installation. Existing sequences that are tested and need programming updates shall be reported to CMS. Programming updates are outside the scope of this project.

Unless a controls item is specifically called out for replacement on RTU equipment schedules, existing downstream equipment controls (non-rooftop equip as in VAV box controls,etc…) shall remain. Any existing device found inoperable or existing sensor found defective during commissioning shall be reported to CMS and marked as deficient. Repair or replacement of these items is CMS' responsibility and is outside the scope of this project. Sequences to be commissioned are as follows: RTU start/stop, cooling ON/OFF, Economizer function, demand control ventilation, building pressurization, and verification of dehumidification operation. The below sequence for VAV boxes is for information only. No commissioning is required for VAV boxes

B. This Section includes control sequences for HVAC systems, sub-systems and equipment.

C. Related Sections include the following:

1. Division 23 Section "Instrumentation and Control for HVAC" for control equipment and devices and for submittal requirements.

1.3 DEFINITIONS

A. DDC: Direct digital control.

B. Set-points: In general, stated set-points are intended to be a starting programming value with the final setup adjustable from BAS.

C. BAS: Building Automation System.

1.4 RTU AIR SYSTEM DX W/VAV (RTU-1,2,3,4,5,6,7,8)

A. The Building Automation System (BAS) shall perform the following RTU Air System (RTU) control strategies, appropriate to the given occupancy mode of the system, as determined by the user-adjustable time-of-day schedule for the system. Optimal start and unoccupied mode applies only to HVACU with time of day scheduled operation. Verify time schedule during Owner's training.

B. Optimal Start Mode:

1. The BAS shall initiate the Optimal Start mode such that the RTU is started and Air terminal units serving the RTU are enabled prior to when the space being served by the RTU is scheduled to be occupied, to allow the zone temperature to reach the pending occupied heating or cooling set-point. The system shall wait as long as possible before starting, so that the temperature in each zone reaches the occupied set-point just in time for scheduled occupancy. Ventilation functions shall be disabled when the RTU is in Optimal Start mode and outside air dampers shall be closed.
2. The BAS shall use a self-adjusting algorithm to calculate the actual time to initiate Optimal Start for the VAV Air System based on the occupied set-point, space temperature, outside air temperature, historical optimal start performance data and the associated heating or cooling optimal start rate.
3. An early start limit shall be provided to prevent the RTU from starting prior to 120 minutes (adjustable) before scheduled occupancy.
4. The RTU shall transition from Optimal Start mode to occupied mode when the current time is equal to the scheduled start time.

    a. Cooling:

        1) The BAS shall initiate the Optimal Start – Cooling mode when Optimal Start mode for the RTU has been initiated and the average temperature of the space is warmer than its occupied cooling set-point. All ventilation functions are disabled while operating in Optimal Start mode and the outside air dampers shall be closed.
        2) The BAS shall determine the length of time required to lower the space temperature to the occupied cooling set-point when the mode of the RTU is cooling and the space temperature is above the occupied cooling set-point.
        3) Each air terminal unit in the VAV Air System shall control to its occupied cooling set-point, and shall modulate box airflow to maintain the space temperature set-point for the zone being served by the Air terminal unit. Auxiliary heat in the Air terminal unit is disabled.
        4) The air handler shall modulate its airflow to maintain the duct static pressure set-point.

    b. Heating:

        1) The BAS shall initiate the Optimal Start – Heating mode, Air terminal unit local heat, when Optimal Start mode has been initiated and the average space temperature is cooler than its occupied heating set-point. All ventilation functions are disabled while operating in Optimal Start mode and the outside air dampers shall be closed.
        2) The BAS shall determine the length of time required to raise the average space temperature to the occupied heating set-point when the mode of the RTU is heating and the average space temperature is below the set-point.
        3) Each Air terminal unit in the VAV Air System shall control to its occupied heating set-point, and shall modulate box airflow to maintain the space temperature set-point for the zone being served by the Air terminal unit. Auxiliary heat in the Air terminal unit is enabled.
        4) The air handler shall modulate its airflow to maintain the duct static pressure set-point.

C. Unoccupied Mode:

1. The BAS shall place the members of the VAV Air System into Off/Standby mode as determined by the user-adjustable time-of-day schedule for the system. The Air terminal units shall control to their individual unoccupied temperature set-points, and all ventilation functions shall be disabled and outside air dampers shall be closed. Air terminal unit local reheat is disabled while the RTU is in unoccupied mode.

2. After the Air terminal units have been commanded to unoccupied, the RTU shall command the associated AHU to Unoccupied mode. Supply fan shall be shut down, heating shall fail to open, cooling shall go to 50%, outdoor air damper shall be closed, and all ventilation functions shall be disabled.

D. Night Setback Mode: During scheduled unoccupied hours, the VAV Air System shall be controlled by the BAS to maintain the unoccupied heating and cooling set-points, as appropriate. Ventilation functions are disabled, the outdoor air damper shall remain closed, unless outdoor air is used for economizing during unoccupied zone cooling. Unless otherwise stated, the RTU supply fan shall operate in the automatic control mode, cycling on only when heating or cooling is needed.

1. Heating:

   a. RTU supply fan energized, Air terminal unit local reheat is used.
   b. The BAS shall initiate the Night Heating mode when the temperature for the space being served by the RTU is less than 55 degrees F (adjustable) in a minimum of 3 rooms, (adjustable). Night heating shall terminate when the space temperature rises above the Unoccupied Heating set-point plus the unoccupied heating differential (4 degrees F, adjustable).
   c. Each Air terminal unit that is associated with the RTU shall control to its unoccupied heating set-point, and shall modulate box airflow to maintain the space temperature set-point for the zone being served by the Air terminal unit.
   d. The air handler shall operate to maintain duct static pressure while in Night Heat mode.
   e. The Air terminal unit shall control its airflow to its maximum heat set-point.

2. Cooling:

   a. RTU supply fan energized
   b. The BAS shall initiate the Night Cooling mode when the temperature for the space being served by the RTU is greater than 85 degrees F, (adjustable) for a minimum of three rooms (adjustable). Night cooling shall terminate when the space temperature falls below the Unoccupied Cooling set-point plus the unoccupied cooling differential (4 degrees F, adjustable).
   c. Each Air terminal unit that is associated with the RTU shall control to its unoccupied cooling set-point, and shall modulate box airflow to maintain the space temperature set-point for the zone being served by the Air terminal unit.
   d. The air handler shall operate to maintain duct static pressure while in Night Cooling mode.

E. Static Pressure Optimization:

1. The building automation system (BAS) shall continuously monitor the damper position of all air terminal units. The discharge duct static pressure shall be sensed 2/3 of the distance from the discharge of each rooftop/air handling unit. The sensor must be mounted in a non-turbulent location. Label the location of the sensor on the ceiling. The BAS shall also read the status on the supply air sensor and display the pressure reading on the status screen. Provide a high pressure switch at the unit with a setpoint between 4” and 6” (adjustable).
2. The building automation system shall monitor the damper position of all air terminal units and determine each air terminal critical zone VAV terminal (CZ), which is the air terminal unit that is the widest open.
3. When any air terminal damper is more than 75 percent (adj.) open, the supply fan discharge duct static pressure set-point shall be reset upward by 0.3 in W.C. (adj.), at a frequency of 15 minutes (adj.), until no damper is more than 75 percent open or the static pressure set-point has reset upward to the system maximum duct static pressure set-point or the supply fan variable-frequency drive is at the maximum speed setting.

4. When all air terminal dampers are less than 65 percent (adj.) open, the supply fan discharge duct static pressure set-point shall be reset downward by 0.3 in W.C. (adj.), at a frequency of 15 minutes (adjustable), until at least one damper is more than 65 percent open or the static pressure set-point has reset downward to the system minimum duct static pressure set-point.
5. Air terminal units in calibration or auto commissioning mode shall not impact the critical zone calculation.
6. The control bands, set-point increment values, set-point decrement values and adjustment frequencies shall be adjusted to maintain maximum static pressure optimization with stable system control and maximum comfort control.

F. Occupied Mode Cooling Control: The compressors shall energize to maintain the discharge air temperature at the discharge cooling set-point for the RTU. The VAV's shall modulate the air flow to maintain the zone temp per the cooling set point.

G. Occupied Mode Heating Control: Heating during Occupied Mode shall be controlled via the Air Terminal Unit section of this specification.

H. Economizer - Enthalpy Enable:

1. The mixed air temperature set point shall be 2°F (adj.) less than the supply air temperature set point. The controller shall measure the mixed air temperature and modulate the economizer dampers in sequence to maintain this set point.
2. The outside air damper shall close and the return air damper shall open when the unit is off.
3. The economizer shall be enabled whenever:

    a. Outside air temperature is less than 65°F (adj.).
    b. AND the outside air enthalpy is less than 22Btu/lb (adj.)
    c. AND the outside air temperature is less than the return air temperature.
    d. AND the outside air enthalpy is less than the return air enthalpy.
    e. AND the fan status is on.

4. The economizer shall close to 0% (adj.) whenever:

    a. The freezestat is on.
    b. OR the mixed air temperature is less than 35°F (adj.).
    c. OR on loss of fan status.

5. Alarms shall be provided as follows:

    a. High Mixed Air Temp: If the mixed air temperature is 5°F (adj.) greater than set point.
    b. Low Mixed Air Temp: If the mixed air temperature is 5°F (adj.) less than set point.

I. Dehumidification:

1. Provide all necessary sensors for dehumidification control at each air handler.
2. The controller shall measure the return air humidity and override the cooling sequence to maintain a return air humidity setpoint of 60% rh (adj.). The dehumidification shall turn off whenever the return air humidity drops below 55% rh (adj.).

    a. When dehumidification mode is engaged per the requirements above, the unit shall go to cooling mode with the terminal units providing space temperature control.

3. Dehumidification shall be enabled whenever:

a. Fan status is on
b. Zone humidity exceeds 60% (adj.) relative humidity in unoccupied mode.

4. Alarms shall be provided as follows:

a. High Return Air Humidity: If the return air humidity is 10% rh (adj.) greater than setpoint.
b. Low Return Air Humidity: If the return air humidity is 10% rh (adj.) less than setpoint.

J. Safety Interlock: The following shall de-energize the RTU supply fan: Duct detector, emergency stop button, low limit thermostat activation, high Pressure switch (4"-6" adjustable).

K. Building Pressurization

1. The exhaust/relief damper shall modulate open to maintain a building pressurization of +0.05" (adj.) SP as measured by a space pressurization sensor.
2. There shall be one sensor per air handler.
3. There shall be an alarmed condition for space pressurization rising more than 25% (adj.) above the setpoint and for space pressurization falling more than 25% (adj.) below the setpoint.

L. Demand Control Ventilation

1. Outside air intake shall be provided with a motorized damper. On unit start up, the outside air intake damper shall remain closed until the return air temperature rises above 65° f (adj) or falls below 75° f. (adj). Once return air temperature is satisfied, the outside air damper shall open to the occupied minimum setpoint. Outside air dampers shall modulate as required to maintain minimum outside air flow. the outside air intake damper shall be closed while unit is in the unoccupied mode. BAS shall be capable of opening and closing outside air dampers. CO2 sensor mounted in the return duct shall modulate the outside air damper based on co2 levels in the space. Damper shall modulate open from the occupied minimum setpoint of 800 ppm to design maximum at 1200 ppm. An alarm shall be activated if the space co2 level rises above 1500 ppm. See AHU schedule for minimum and design outside air setpoints.

Variable Air Volume - AHU DX

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Building Static Pressure	x								x		x
Mixed Air Temp	x				x				x		x
Return Air Carbon Dioxide PPM	x								x		x
Return Air Humidity	x				x				x		x
Return Air Temp	x				x				x		x
Supply Air Static Pressure	x				x				x	x	x
Supply Air Temp	x				x				x		x
Exhaust Air Damper		x									x
Mixed Air Dampers		x			x				x		x
Supply Fan VFD Speed		x							x		x

Exhaust Air Damper Status			x						x		x
High Static Shutdown			x						x	x	x
Smoke Detector			x						x	x	x
Fan Status (depended on number / type of fans)			x			x			x		x
Supply Fan VFD Fault			x							x	x
Cooling Stage 1				x		x			x		x
Cooling Stage 2				x		x			x		x
Cooling Stage 3				x		x			x		x
Cooling Stage 4				x		x			x		x
Supply Fan Start/Stop				x					x		x
Building Static Pressure Set-point					x						x
Dehumidification Setpoint					x				x		x
Economizer Mixed Air Temp Setpoint					x				x		x
Return CO2 Setpoint					x				x		x
Supply Air Static Pressure Set-point					x				x		x
Supply Air Temp Setpoint					x				x		x
Emergency Shutdown						x				x	x
Exhaust Air Damper Failure										x	
High Return Air Carbon Diox-ide Concentration										x	
High Return Air Humidity										x	
High Supply Air Temp										x	
High Zone Carbon Dioxide Concentration										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	

*Controls are by the unit manufacturer. EMS will monitor / control via the BACnet interface only. Red indicate monitoring points, Green are commanded points.

1.5 SINGLE ZONE VARIABLE AIR VOLUME DX AIR HANDLING UNIT w/HW DUCT REHEAT OPERATON (RTU-10)

A. The Building Automation System (BAS) shall perform the following Single Zone VAV Air System (SZVAS) control strategies, appropriate to the given occupancy mode of the system, as determined by the user-adjustable time-of-day schedule for the system. Optimal start and unoccupied mode applies only to HVACU with time of day scheduled operation. Verify time schedule during Owner's training.

B. Optimal Start Mode:

1. The BAS shall initiate the Optimal Start mode such that the SZVAV air handler is started prior to when the space being served by the SZVAS is scheduled to be occupied, to allow the zone temperature to reach the pending occupied heating or cooling set-point. The system shall wait as long as possible before starting, so that the temperature in each zone reaches the occupied set-point just in time for scheduled occupancy. Ventilation functions shall be disabled when the SZVAS is in Optimal Start mode and outside air dampers shall be closed.
2. The BAS shall use a self-adjusting algorithm to calculate the actual time to initiate Optimal Start for the SZVAV Air System based on the occupied set-point, space temperature, outside air temperature, historical optimal start performance data and the associated heating or cooling optimal start rate.
3. An early start limit shall be provided to prevent the SZVAS from starting prior to 120 minutes (adjustable) before scheduled occupancy.
4. The SZVAS shall transition from Optimal Start mode to occupied mode when the current time is equal to the scheduled start time.

    a. Cooling:

        1) The BAS shall initiate the Optimal Start – Cooling mode when Optimal Start mode for the SZVAS has been initiated and the temperature of the space is warmer than its occupied cooling set-point. All ventilation functions are disabled while operating in Optimal Start mode and the outside air dampers shall be closed.
        2) The BAS shall determine the length of time required to lower the space temperature to the occupied cooling set-point when the mode of the SZVAS is cooling and the space temperature is above the occupied cooling set-point.
        3) The dx compressors shall stage on and the air handler fan shall operate at low speed until the space temperature is satisfied. Upon a further rise in space temperature, fan variable frequency drive shall increase air flow to satisfy space temperature.

    b. Heating:

        1) The BAS shall initiate the Optimal Start – Heating mode when Optimal Start mode has been initiated and the space temperature is cooler than its occupied heating set-point. All ventilation functions are disabled while operating in Optimal Start mode and the outside air dampers shall be closed

        2) The BAS shall determine the length of time required to raise the space temperature to the occupied heating set-point when the mode of the SZVAS is heating and the space temperature is below the set-point.

        3) The local duct mounted hot water reheat coils 2-way valves shall modulate to maintain setpoint and the air handler fan shall operate at 60% speed during heating mode. Each hot water coil unit shall control to its occupied heating set-point

C. Unoccupied Mode:

1. The BAS shall place the members of the SZVAV Air System into Off/Standby mode as determined by the user-adjustable time-of-day schedule for the system. The AHU shall control to the individual unoccupied temperature set-point, and all ventilation functions shall be disabled and outside air dampers shall be closed.
2. After the zone has been commanded to unoccupied, the SZVAS shall command the associated AHU to Unoccupied mode. Supply fan shall be shut down, heating and cooling shall be deactivated, outdoor air damper shall be closed, and all ventilation functions shall be disabled.

D. Night Setback Mode: During scheduled unoccupied hours, the SZVAV Air System shall be controlled by the BAS to maintain the unoccupied heating and cooling set-points, as appropriate. Ventilation functions are disabled, the outdoor air damper shall remain closed, unless outdoor air is used for economizing during unoccupied zone cooling. Unless otherwise stated, the AHU supply fan shall operate in the automatic control mode, cycling on only when heating or cooling is needed.

1. Heating:

    a. AHU supply fan energized at 60% speed, local hot water coils shall modulate based on space temp setpoint.
    b. The BAS shall initiate the Night Heating mode when the temperature for the space being served by the SZVAS is less than 55 degrees F (adjustable). Night heating shall terminate when the space temperature rises above the Unoccupied Heating set-point plus the unoccupied heating differential (4 degrees F, adjustable).

2. Cooling:

    a. AHU supply fan energized at low speed, dx compressors shall stage as required.
    b. The BAS shall initiate the Night Cooling mode when the temperature for the space being served by the VAS is greater than 85 degrees F, (adjustable) Night cooling shall terminate when the space temperature falls below the Unoccupied Cooling set-point plus the unoccupied cooling differential (4 degrees F, adjustable).

E. Occupied Mode Cooling Control: The dx compressors shall stage, and the fan variable frequency drive shall modulate to maintain the space temperature.

F. Occupied Mode Heating Control: The local hot water reheat coils shall modulate, and the fan variable frequency drive shall operate at 60%,

G. Economizer - Enthalpy Enable:

1. The mixed air temperature set point shall be 2°F (adj.) less than the supply air temperature set point. The controller shall measure the mixed air temperature and modulate the economizer dampers in sequence to maintain this set point.
2. The outside air damper shall close and the return air damper shall open when the unit is off.
3. The economizer shall be enabled whenever:

    a. Outside air temperature is less than 65°F (adj.).
    b. AND the outside air enthalpy is less than 22Btu/lb (adj.)
    c. AND the outside air temperature is less than the return air temperature.
    d. AND the outside air enthalpy is less than the return air enthalpy.
    e. AND the fan status is on.

4. The economizer shall close to 0% (adj.) whenever:

    a. The freezestat is on.
    b. OR the mixed air temperature is less than 35°F (adj.).
    c. OR on loss of fan status.

5. Alarms shall be provided as follows:

    a. High Mixed Air Temp: If the mixed air temperature is 5°F (adj.) greater than set point.
    b. Low Mixed Air Temp: If the mixed air temperature is 5°F (adj.) less than set point.

H. Dehumidification:
1. Provide all necessary sensors for dehumidification control at each air handler.
2. The controller shall measure the return air humidity and override the cooling sequence to maintain a return air humidity setpoint of 60% rh (adj.). The dehumidification shall turn off whenever the return air humidity drops below 55% rh (adj.).
   a. When dehumidification mode is engaged per the requirements above, the unit shall go to cooling mode with the duct mounted hot water coils providing space temperature control.
3. Dehumidification shall be enabled whenever:
   a. Fan status is on
   b. Zone humidity exceeds 60% (adj.) relative humidity in unoccupied mode.
4. Alarms shall be provided as follows:
   a. High Return Air Humidity: If the return air humidity is 10% rh (adj.) greater than setpoint.
   b. Low Return Air Humidity: If the return air humidity is 10% rh (adj.) less than setpoint.

I. Safety Interlock: The following shall de-energize the AHU supply fan: Duct detector, emergency stop button, low limit thermostat activation, high Pressure switch (4"-6" adjustable).

J. Building Pressurization

1. The exhaust/relief damper shall modulate open to maintain a building pressurization of +0.05" (adj.) SP as measured by a space pressurization sensor.
2. There shall be one sensor per air handler.
3. There shall be an alarmed condition for space pressurization rising more than 25% (adj.) above the setpoint and for space pressurization falling more than 25% (adj.) below the setpoint.

K. Demand Control Ventilation
1. Outside air intake shall be provided with a motorized damper. On unit start up, the outside air intake damper shall remain closed until the return air temperature rises above 65° f (adj) or falls below 75° f. (adj). Once return air temperature is satisfied, the outside air damper shall open to the occupied minimum setpoint. Outside air dampers shall modulate as required to maintain minimum outside air flow. the outside air intake damper shall be closed while unit is in the unoccupied mode. BAS shall be capable of opening and closing outside air dampers. CO2 sensor mounted in the return duct shall modulate the outside air damper based on co2 levels in the space. Damper shall modulate open from the occupied minimum setpoint of 800 ppm to design maximum at 1200 ppm. An alarm shall be activated if the space co2 level rises above 1500 ppm. See AHU schedule for minimum and design outside air setpoints.

Single Zone VAV Unit - DX

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Mixed Air Temp	x								x		x
Outside Air Humidity	x								x		x
Outside Air Temp	x								x		x
Return Air Carbon Dioxide PPM	x								x		x
Return Air Humidity	x								x		x
Return Air Temp	x								x		x
Supply Air Temp	x								x		x

Zone Setpoint Adjust	x										x
Zone Temp	x								x		x
Mixed Air Dampers		x							x		x
Supply Fan VFD Speed		x							x		x
Smoke Detector			x						x	x	x
Fan Status (depended on number / type of fans)						x			x		x
Supply Fan VFD Fault			x						x		x
Zone Override			x						x		x
Cooling Stage 1				x					x		x
Cooling Stage 2				x					x		x
Cooling Stage 3				x					x		x
Cooling Stage 4				x					x		x
Supply Fan Start/Stop				x					x		x
Cooling Setpoint					x				x		x
Economizer Zone Temp Set-point					x				x		x
Heating Setpoint					x				x		x
Return Air Carbon Dioxide PPM Setpoint					x				x		x
Emergency Shutdown						x				x	x
High Return Air Carbon Diox-ide Concentration										x	
High Return Air Humidity										x	
Supply Fan Failure										x	
Supply Fan in Hand										x	

*Controls are by the unit manufacturer. EMS will monitor / control via the BACnet interface only. Red indicate monitoring points, Green are commanded points.

1.6 CONSTANT VOLUME ROOFTOP DX UNIT w/HW DUCT REHEAT OPERATON (RTU-9)

A. The Building Automation System (BAS) shall perform the following control strategies, appropriate to the given occupancy mode of the system, as determined by the user-adjustable time-of-day schedule for the system. Optimal start and unoccupied mode applies only to HVACU with time of day scheduled operation. Verify time schedule during Owner's training.

B. Optimal Start Mode:

1. The BAS shall initiate the Optimal Start mode such that the unit is started and enabled prior to when the space being served by the unit is scheduled to be occupied, to allow the zone temperature to reach the pending occupied heating or cooling set-point. The system shall wait as long as possible before starting, so that the temperature reaches the occupied set-point just in time for scheduled

occupancy. Ventilation functions shall be disabled when the unit is in Optimal Start mode and outside air dampers shall be closed.

2. The BAS shall use a self-adjusting algorithm to calculate the actual time to initiate Optimal Start for the unit based on the occupied set-point, space temperature, outside air temperature, historical optimal start performance data and the associated heating or cooling optimal start rate.
3. An early start limit shall be provided to prevent the unit from starting prior to 120 minutes (adjustable) before scheduled occupancy.
4. The unit shall transition from Optimal Start mode to occupied mode when the current time is equal to the scheduled start time.

    a. Cooling:

        1) The BAS shall initiate the Optimal Start – Cooling mode when Optimal Start mode for the unit has been initiated and the average temperature of the space is warmer than its occupied cooling set-point. All ventilation functions are disabled while operating in Optimal Start mode and the outside air dampers shall be closed.
        2) The BAS shall determine the length of time required to lower the space temperature to the occupied cooling set-point when the mode of the unit is cooling and the space temperature is above the occupied cooling set-point.
        3) The unit shall control to its occupied cooling set-point, and shall modulate compressor(s) to maintain the space temperature set-point for the zone being served.

    b. Heating:

        1) The BAS shall initiate the Optimal Start – Heating mode, when Optimal Start mode has been initiated and the average space temperature is cooler than its occupied heating set-point. All ventilation functions are disabled while operating in Optimal Start mode and the outside air dampers shall be closed.
        2) The BAS shall determine the length of time required to raise the average space temperature to the occupied heating set-point when the mode of the unit is heating and the average space temperature is below the set-point.
        3) The duct mounted hot water reheat coils 2-way valves shall modulate to maintain setpoint. Each hot water coil unit shall control to its occupied heating set-point

C. Unoccupied Mode:

1. The BAS shall place the unit into Off/Standby mode as determined by the user-adjustable time-of-day schedule for the system. The unit shall control to the unoccupied temperature set-point, and all ventilation functions shall be disabled and outside air dampers shall be closed.

D. Night Setback Mode: During scheduled unoccupied hours, the unit shall be controlled by the BAS to maintain the unoccupied heating and cooling set-points, as appropriate. Ventilation functions are disabled, the outdoor air damper shall remain closed.. Unless otherwise stated, the supply fan shall operate in the automatic control mode, cycling on only when heating or cooling is needed.

1. Heating:

    a. AHU supply fan energized local hot water coils shall modulate based on space temp setpoint.
    b. The BAS shall initiate the Night Heating mode when the temperature for the space being served by the unit is less than 55 degrees F (adjustable). Night heating shall terminate when the space temperature rises above the Unoccupied Heating set-point plus the unoccupied heating differential (4 degrees F, adjustable).

2. Cooling:

a. AHU supply fan energized
b. The BAS shall initiate the Night Cooling mode when the temperature for the space being served by the unit is greater than 85 degrees F, (adjustable). Night cooling shall terminate when the space temperature falls below the Unoccupied Cooling set-point plus the unoccupied cooling differential (4 degrees F, adjustable).

E. Occupied Mode Cooling Control: The compressors shall modulate to maintain the space temperature.

F. Occupied Mode Heating Control: The local hot water reheat coils shall modulate, and the fan shall energize.

1. Alarms shall be provided as follows:

a. High Mixed Air Temp: If the mixed air temperature is 5°F (adj.) greater than set point.
b. Low Mixed Air Temp: If the mixed air temperature is 5°F (adj.) less than set point.

G. Safety Interlock: The following shall de-energize the supply fan: Duct detector, emergency stop button.

Single Zone Unit - DX

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Mixed Air Temp	m								m		m
Outside Air Humidity	x								x		x
Outside Air Temp	x								x		x
Return Air Humidity	m								m		m
Return Air Temp	m								m		m
Supply Air Temp	m								m		m
Zone Setpoint Adjust	x										x
Zone Temp	m								m		m
Mixed Air Dampers		x							x		X
Smoke Detector			X						x	x	x
Fan Status (depended on number / type of fans)						m			m		m
Zone Override			X						x		X
Cooling Stage 1				m					m		m
Cooling Stage 2				m					m		m
Cooling Stage 3				m					m		m
Cooling Stage 4				m					m		m
Supply Fan Start/Stop				x					x		X
Cooling Setpoint					c				c		c

Heating Setpoint					c				c		c
Emergency Shutdown						c				c	c
Supply Fan Failure										x	
Supply Fan in Hand										x	

*Controls are by the unit manufacturer. EMS will monitor / control via the BACnet interface only. "m" indicate monitoring points, "c" are commanded points.

1.7 AIR TERMINAL UNIT OPERATION ***(FOR SEQUENCE INFORMATION ONLY EXISTING VAV BOXES AND ASSOCIATED CONTROLS TO REMAIN)***

A. Direct Digital Controls: DDC controls, actuators and costs to mount, calibrate and test the system shall be the responsibility of controls Contractor.

B. Terminal Unit Control:

1. The terminal box units shall be individually controlled by a DDC terminal controller per terminal unit.
2. The BAS shall perform the following terminal unit control strategies and provide the points as listed on the DDC terminal point list and the specified monitoring and diagnostics.

a. Set point Control: The BAS shall edit the zone space temperature set-point of each terminal box. The zone temperature set-point shall be operator adjustable. Individual zone set-point and control logic shall reside at the zone level and shall not be dependent upon the BAS for control. In the event of communication loss, the box shall continue to control to current set-points.
b. Cooling Valve Control: The BAS shall control the cooling air valve to a fully open, fully closed, maximum CFM or minimum CFM position based on operator commands. The operator shall also have the capability to adjust the maximum and minimum airflow limits of the air valve through the BAS.
c. Operating Mode: The BAS shall place the box in either the occupied or unoccupied mode based on an operator adjustable time schedule. Separate heating and cooling set-points shall be provided for each mode through the BAS. Other modes available for special applications shall include full open, full closed, maximum flow and minimum flow.
d. Occupied Mode: As the space temperature rises above the cooling set-point, the terminal unit shall modulate to its maximum CFM set-point. As the space temperature falls below cooling set-point, the terminal unit shall modulate to its minimum CFM set-point. Upon a further decrease in space temperature, the terminal unit shall modulate to heating CFM and the heating coil (when provided) shall modulate.
e. Unoccupied Mode: During this mode, the air valve on the terminal unit shall be closed. When required by the unoccupied set-point, the heat shall cycle to maintain a reduced space temperature. Unit shall be at minimum heating CFM when heat is energized.
f. Morning warm-up Mode: The air valve on the terminal unit shall modulate to their maximum heating CFM and the heating coil shall cycle to maintain the occupied heating set-point.

g. The building automation system shall provide the ability to automatically commission and calibrate the terminal Air System. The following tests shall be performed, at a minimum: Calibration of the air valve/damper, Verification of air flow through the terminal box, Verification of local reheat performance.

h. The building automation system (BAS) shall provide the ability to initiate the auto-commissioning/auto-calibration command directly from the user interface. Special service tools shall not be required. The terminal boxes shall allow the operator to perform on an individual or group basis auto-commissioning report for the terminal Air System which contains the results of the auto-commissioning/auto-calibration tests which is printable and

i. remain in memory until the next auto-commissioning test is initiated. This report shall contain, at a minimum, the following information for each terminal box in the system. Name of terminal box. Date and time the terminal box was tested. Presence of any alarms. Space temperature and set-point. Active airflow (in CFM). Air valve/damper position at every 5% increment. Discharge air temperature of the terminal box when the hot heat is active.

C. Zone Thermostats:

1. The zone thermostats shall be accurate to within 1.0 degrees F. The thermostats shall be provided by the controls contractor and shall be as noted in section 230900 space thermostats (2.12G).
2. The zone thermostat shall be installed to avoid relaying false temperatures (i.e. not close to heating/cooling sources).

Air Terminal Unit	**Hardware Points**				**Software Points**						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Airflow	x								x		x
Discharge Air Temp	x								x		x
Zone Temp	x								x		x
Zone Setpoint Adjustment (where required)	x								x		x
Zone Override (where re-quired)			x						x		x
Reheating Valve (when re-quired)		x							x		x
Zone Damper		x							x		x
Airflow Setpoint					x				x		x
Cooling Setpoint					x				x		x
DAT Heating Limit					x						
Heating Setpoint					x				x		x
Percent of Time Satisfied					x				x		
Heating Mode						x			x		
Schedule								x			

1.8 SMOKE DETECTOR OPERATION

A. When particles of combustion are detected by the duct mounted smoke detector, stop the HVACU supply fan, close the outside damper and stop the fans in all air terminal units associated with the HVACU.

B. Refer to Division 26 Fire Alarm Section for duct mounted smoke detectors.

C. Smoke detectors and sampling tubes shall be furnished by the electrical contractor for installation by the mechanical contractor. Sampling tubes shall be connected under electrical and installed under the mechanical section of this specification.

Smoke Detector Operation	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Smoke Detector Status*			x						x	x	x
Smoke shutdown command						x			x	x	x

*Monitor Smoke detector status on detectors on each HVACU.

1.9 FIRE ALARM INTERFACE

A. The BAS shall shut-down all air handling equipment as required by code upon contact closure by a remote fire alarm relay located adjacent to the BAS control panel. The HVAC equipment shall de-energize based on whether the dedicated smoke detector or the general alarm contact for that floor is in alarm. The equipment shall include, but not be limited to the following:

1. Central Air Handling Units.
2. Air terminal units.
3. Toilets riser exhaust fans.
4. Janitor riser exhaust fan.
5. Building main relief fan.
6. Fan coil units.

Fire Alarm Interface	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
FA Remote Relay Status*			x						x	x	x
FA Remote Relay shutdown command**						x			x	x	x

*Monitor FA Remote Relay status on relays next to each HVACU control panel.

**Remote shutdown command shall shutdown equipment by floor or area based on local relay status. HVACU, terminal units and fans included.

Variable Frequency Drive Interface

	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Start / Stop*				x					x		x
Speed*		x							x		x
Motor Current Amps					x				x		x
Motor Frequency Hertz					x				x		x
Motor Runtime					x						x
Motor Speed RPM					x				x		x
In Fault Condition						x			x	x	x
VFD Status						x			x		x

*Note: All VFDs shall have Start/Stop, Status and Speed as **hardwired** direct contact points. Other listed points shall be provided via a BACnet interface.

1.10 HOT WATER DUCT COILS

A. Direct Digital Controls: existing DDC controls devices may be reused to achieve sequence of operations. Except for devices called out for replacement on RTU schedules.

B. HW Coil Control:

1. The BAS shall perform the following hot water coil control strategies and provide the points as listed on the DDC terminal point list and the specified monitoring and diagnostics.

   a. Set point Control: The BAS shall edit the zone space temperature set-point of each zone. The zone temperature set-point shall be operator adjustable. Individual zone set-point and control logic shall reside at the zone level and shall not be dependent upon the BAS for control. In the event of communication loss, the coil shall continue to control to current set-points.
   b. Operating Mode: The BAS shall place the coil in either the occupied or unoccupied mode based on an operator adjustable time schedule. Separate heating and cooling set-points shall be provided for each mode through the BAS.
   c. Occupied Mode: As the space temperature falls below cooling set-point the heating coil control valve shall modulate to maintain space temperature.
   d. Unoccupied Mode: When required by the unoccupied set-point, the heating coil control valve shall modulate to maintain space temperature.
   e. Morning warm-up Mode: the heating coil control valve shall modulate to maintain to maintain the occupied heating set-point.

C. Zone Thermostats:

1. The zone thermostats shall be accurate to within 1.0 degrees F. The thermostats shall be provided by the controls contractor and shall be as noted in section 230900 space thermostats (2.12G).
2. The zone thermostat shall be installed to avoid relaying false temperatures (i.e. not close to heating/cooling sources).

Hot Water Duct Coil	Hardware Points				Software Points						
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Loop**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Discharge Air Temp	x								x		x
Zone Temp	x								x		x
Zone Setpoint Adjustment	x								x		x
Zone Override			x						x		x
Reheating Valve		x							x		x
Cooling Setpoint					x				x		x
DAT Heating Limit					x						
Heating Setpoint					x				x		x
Percent of Time Satisfied					x				x		
Heating Mode						x			x		
Schedule								x			

END OF SECTION 230993