SECTION 230993 - SEQUENCE OF OPERATIONS FOR HVAC DDC

PART 1 - GENERAL

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

1.2 SUMMARY
   A. Section includes control sequences for DDC for HVAC systems, subsystems, and equipment.
   B. Related Requirements:
      1. Section 230923 "DDC Systems for HVAC" for control equipment.

1.3 GENERAL
   A. All HVAC Systems shall be controlled thru the BAS according to this section.
   B. Additional points and programming not listed in the point list but that is required to meet the sequences of operation shall be provided.
   C. Provide custom points and overrides as directed by the commissioning agent to facilitate the commissioning of the system.
   D. All control loops shall utilize PID control algorithms unless otherwise specified.
   E. All setpoints and control parameters shall be adjustable both from the desktop workstation and portable workstation primary operation interface software.
   F. Provide feedback position as a BAS system analog input on each actuator.
   G. All HVAC safeties shall be hardwired such that the shutdown will occur both in automatic and hand modes of operation

1.4 DEFINITIONS
   A. Analog Output: Proportional output signal (zero- to 10-V dc, 4 to 20 mA).
   B. Binary Output: On/off output signal or contact closure.
   C. DDC: Direct digital control.
   D. Digital Output: Data output that must be interpreted digitally.
1.5 VARIABLE AIR VOLUME RTU’s – RTU-1, EF-9 & EF-10

A. Design intent:
   1. This unit is a variable air volume unit that provides conditioning for multiple areas of the building.
   2. Temperature control is provided by a gas heating section and a DX cooling coil.
   3. The units shall be provided with factory and field installed controls. Factory controls shall include control of the DX refrigeration section. Field installed controls shall control all other components.
   4. The BAS and the RTUs shall communicate as required to allow the custom sequence of operation.
   5. The units shall have a VFD on the supply fan.
   6. The units shall have a modulating outside air damper.
   7. The units shall have a modulating return air damper.
   8. Air flow stations shall be installed on the outside air intake.

B. Safeties
   1. A smoke detector shall be installed downstream of the supply fan and shall shut the unit off if alarmed.
   2. A high duct static pressure sensor shall be installed in the discharge air ductwork within 5’ of the unit and shut the unit down if the duct static pressure is above 3” (adjustable).
   3. A low duct static pressure sensor shall be installed in the exhaust (return) air ductwork within 5’ of the unit and shut the unit down if the duct static pressure is below 2” (adjustable).

C. General:
   1. The unit shall operate based on an Owner defined occupied/unoccupied time of day schedule.
   2. When the unit is off, the following shall occur:
      a. The OA damper shall close.
      b. The RA Damper shall open.
      c. The DX cooling shall be off.
      d. The gas heat shall be off.
      e. The supply fan shall be off.
   3. When the start signal is given:
      a. The OA and RA dampers shall open and modulate in conjunction to provide scheduled minimum outside air CFM.
      b. All PID control shall be released to automatic.

D. Minimum Outside Air Volume Control:
   1. The BAS shall modulate the outside and return air dampers to maintain the scheduled minimum OA CFM when the fume hoods are off (EF-9 and EF-10).
   2. When the fume hood served by EF-9 is energized/on, increase the minimum OA CFM by 400 CFM.
   3. When the fume hood served by EF-10 is energized/on, increase the minimum OA CFM by 300 CFM.

E. Supply Static Pressure Control:
1. When the unit is in air side economizer, modulate the supply fan VFD to maintain a minimum of 1.5” WC (adjustable) of positive supply duct pressure with respect to the remote duct static pressure sensor.

2. When the unit is in heating or cooling, proportionally reset the duct static pressure setpoint from 1.0” WC to 1.5” WC (adjustable) from the worst case VAV box cooling demand as follows:

<table>
<thead>
<tr>
<th>Worst Case VAV Box % Cooling Demand</th>
<th>Static Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% or below</td>
<td>1.0” WC</td>
</tr>
<tr>
<td>90% or above</td>
<td>1.5” WC</td>
</tr>
</tbody>
</table>

3. The supply duct static pressure sensor shall be located approximately 2/3’s of the distance of the main supply duct run. Reference the mechanical drawings for the location.

4. The pressure transmitter shall be located in a straight piece of duct to prevent inaccurate readings.

5. Provide a hardwired, high limit duct static pressure safety in the main supply discharge duct.

F. Discharge Air Temperature Control:
1. Modulate the gas heat section, air side economizer and DX cooling coil to maintain the unit discharge air set point.
2. When the unit is in heating or cooling, the discharge air temperature set point shall be 55 F (adjustable).
3. When the unit is in air side economizer, proportionally reset the discharge air setpoint from 55 F to 65 F (adjustable) from the worst case VAV box cooling demand as follows:

<table>
<thead>
<tr>
<th>Worst Case VAV Box % Cooling Demand</th>
<th>Discharge Air Set point</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% or below</td>
<td>65 F</td>
</tr>
<tr>
<td>90% or above</td>
<td>55 F</td>
</tr>
</tbody>
</table>

G. Air Side Economizer Control:
1. When the outside air enthalpy is less than the return air enthalpy, modulate the outside and return air dampers and the DX cooling coil to maintain the discharge air temperature set point.
2. The DX cooling coil shall be used to trim as needed.
3. When the outside air enthalpy is greater than the return air enthalpy, the outside air and return air dampers shall return to its minimum OA CFM.

H. Occupied/Unoccupied Control:
1. The Owner shall provide an Occupied/Unoccupied time of day schedule for each individual FCU.
2. A manual 2 hour override shall be provided at the VAV space mounted temperature sensor.
3. When the space is occupied, the supply fan shall be on and VAV space temperature set point shall be 72 F (adj).
4. When the space is unoccupied, the supply fan shall be off when heating or cooling is not required and cycle on when heating or cooling is required via VAV box. The minimum run time shall be 10 minutes (adj).
5. The heating DAT temperature shall be 90 F (adj).
6. The cooling DAT temperature shall be 55 F (adj).
7. The heating temperature set point shall be 60 F (adj).
8. The cooling temperature set point shall be 80 F (adj).
9. The warming morning up cycle shall be provided per the RTU’s manufacturer.

I. EF-9 and EF-10 shall be interlocked to operate whenever their associated fume hood is manually turned on.

J. Points Lists:
   1. OA Dry Bulb Temperature:       AI
   2. OA % RH:           AI
   3. OA Enthalpy:          AI
   4. SA Fan S/S:          DO
   5. SA Fan VFD Status:        AI
   6. SA Fan VFD Speed         AO
   7. SA Fan VFD Alarm:        DI
   8. Duct Supply Static Pressure Setpoint:    AO
   9. Duct Supply Static Pressure:       AI
10. OA Damper Command:        AO
11. OA Damper – Position:        AI
12. RA Damper Command:        AO
13. RA Damper Position:        AI
14. RA Dry Bulb Temperature:       AI
15. RA % RH:           AI
16. RA Enthalpy:          AI
17. Unit Discharge Air Temperature Setpoint:   AO
18. Safety Alarm(s):             AI
19. EF S/S:            DO
20. EF Status:           DI

1.6 100% OA ROOF TOP UNIT – RTU-3 & EF-6

A. Design intent:
1. This unit is a 100% outside air, single zone, constant volume unit that provides conditioning for the vault areas.
2. Temperature control is provided by a gas heating section and a DX cooling coil.
3. The unit shall be provided with factory and field installed controls. Factory controls shall include control of the gas heating and DX refrigeration section. Field installed controls shall control all other components.
4. The BAS and the RTU shall communicate as required to allow the custom sequence of operation.
5. The unit shall have a VFD or ECM motor on the supply fan for field balancing.
6. The unit shall have a two-position outside air damper.
B. Safeties
   1. A high duct static pressure sensor shall be installed in the discharge air ductwork within 5’ of the unit and shut the unit down if the duct static pressure is above 2” (adjustable).

C. General:
   1. The unit shall operate 24 hours a day.
   2. When the unit is off, the following shall occur:
      a. The OA damper shall close.
      b. The DX cooling shall be off.
      c. The gas heat shall be off.
      d. The supply fan shall be off.
   3. When the start signal is given:
      a. The OA damper shall open and once the OA damper is proven open via an end switch, the supply fan shall be allowed to start.
      b. All PID control shall be released to automatic.

D. If the supply fan is running and fails, provide a 30 second time delay (adjustable) before closing the OA damper to allow the fan to ramp down.

E. Discharge air temperature control:
   1. Modulate the gas heating section and DX cooling coil to maintain the unit discharge air set point.
   2. Proportionally reset the discharge air setpoint from 55 F to 85 F (adjustable) through a cascade control loop to maintain a space temperature setpoint of 72 F (adjustable).

F. EF-6 provides continuous exhaust air for the vault areas and shall operate 24/7.
   1. The EF shall be monitored by the BAS.

G. Points list:
   1. OA % RH: AI
   2. OA Enthalpy: AI
   3. SA Fan S/S: DO
   4. SA Fan VFD Status: AI
   5. SA Fan VFD Speed: AO
   6. SA Fan VFD Alarm: DI
   7. OA Damper: DO
   8. OA Damper – Open: DI
   9. OA Damper – Closed: DI
   10. Unit Discharge Air Temperature Setpoint: AO
   11. Safety Alarm(s): AI
   12. EF S/S: DO
   13. EF Status: DI

1.7 CONSTANT VOLUME ROOF TOP UNIT – RTU-2

A. Design intent:
   1. This unit is a single zone, constant volume unit that provides conditioning for the rack storage area.
   2. Temperature control is provided by a gas heating section and a DX cooling coil.
3. The unit shall be provided with factory and field installed controls. Factory controls shall include control of the gas heating and DX refrigeration section. Field installed controls shall control all other components.

4. The BAS and the RTU shall communicate as required to allow the custom sequence of operation.

5. The unit shall have a VFD or ECM motor on the supply fan for field balancing.

6. The units shall have a modulating outside air damper.

7. The units shall have a modulating return air damper.

B. General:
1. The unit shall operate based on an owner defined occupied/unoccupied time of day schedule.

2. When the unit is off, the following shall occur:
   a. The OA damper shall close.
   b. The RA damper shall be open.
   c. The DX cooling shall be off.
   d. The gas heat shall be off.
   e. The supply fan shall be off.

3. When the start signal is given:
   a. The OA and RA dampers shall open in conjunction to provide scheduled minimum outside air CFM. The OA and RA damper position shall be provided by the test and balance contractor to provide the scheduled minimum OA CFM.
   b. All PID control shall be released to automatic.

C. Discharge air temperature control:
1. Modulate the gas heating section and DX cooling coil to maintain the unit discharge air set point.

2. Proportionally reset the discharge air setpoint from 55 F to 90 F (adjustable) through a cascade control loop to maintain a space temperature setpoint of 72 F (adjustable).

D. Air Side Economizer Control:
1. When the outside air enthalpy is less than the return air enthalpy, modulate the outside and return air dampers and the DX cooling coil to maintain the discharge air temperature set point.

2. The DX cooling coil shall be used to trim as needed.

E. When the outside air enthalpy is greater than the return air enthalpy, the outside air and return air dampers shall return to its minimum OA CFM.

F. XOccluded/Unoccluded Control:

G. The Owner shall provide an Occupied/Unoccupied time of day schedule for each individual FCU.

1. A manual 2 hour override shall be provided by the space mounted temperature sensor.

2. When the space is occupied, the supply fan shall be on and the space temperature set point shall be 72 F (adj).

3. When the space is unoccupied, the supply fan shall be off when heating or cooling is not required and cycle on when heating or cooling is required. The minimum run time shall be 10 minutes (adj).

4. The heating DAT temperature shall be 90 F (adj).
5. The cooling DAT temperature shall be 55 F (adj).
6. The heating temperature set point shall be 60 F (adj).
7. The cooling temperature set point shall be 80 F (adj).

H. Points list:
1. OA % RH: AI
2. OA Enthalpy: AI
3. SA Fan S/S: DO
4. SA Fan VFD Status: AI
5. SA Fan VFD Speed: AO
6. SA Fan VFD Alarm: DI
7. OA Damper Command: AO
8. OA Damper – Position: AI
9. RA Damper Command: AO
10. RA Damper Position: AI
11. Unit Discharge Air Temperature Setpoint: AO
12. Safety Alarm(s): AI

1.8 TERMINAL UNIT CONTROL – VAV BOXES WITH & WITHOUT REHEAT

A. Design Intent:
1. The VAV boxes provide zone temperature control by varying the volume of supply air and energizing the electric re-heat coil when needed (for boxes with re-heat).
2. Some VAV boxes are cooling only.
3. Some VAV boxes have an electric reheat coil with modulating SCR control.
4. VAV boxes with heat shall have a discharge air temperature sensor downstream of the reheat coil.
5. Refer to the mechanical drawings for VAV box CFM values (minimum cooling and heating and maximum cooling and heating).

B. All VAV box controller shall be pressure independent, stand-alone electronic DDC.

C. Cooling Control:
1. The primary air damper shall modulate between the minimum and maximum cooling CFM to maintain the space cooling setpoint of 72 F (adj).

D. Heating Control:
1. Upon a drop in space temperature below the heating setpoint, the airflow shall modulate to the minimum heating CFM.
2. The reheat coil shall modulate to maintain the space heating setpoint of 70 F (adj). The discharge air temperature shall be limited to a maximum temperature of 85 F.
3. If the discharge air temperature set point has been reset up to 85 F for 10 minutes and on a continued drop in space temperature below the space temperature setpoint, the VAV box shall modulate from the minimum heating CFM to the maximum heating CFM to maintain space setpoint. The discharge air temperature shall remain at 85 F during this time.

E. Points List:
1. Space Temperature AI
2. Primary Air Valve Position: AO
3. Primary Air CFM: AI
4. Heating Water Valve Command: AO
5. Heating Water Valve Position: AI
6. Discharge Air Temperature: AI

1.9 TERMINAL UNIT CONTROL – VAV BOXES RTU1-3-H (DRY ROOMS)

A. Design Intent:
1. This VAV box provide make-up air and zone temperature control for the Dry Rooms.
2. The VAV box shall provide a constant airflow to the dry rooms. The VAV damper shall modulate to maintain the VAV box’s scheduled CFM.
3. The electric re-heat coil shall modulate to maintain space temperature.

1.10 TERMINAL UNIT CONTROL – VAV BOXES RTU1-4-H & RTU1-5-H (FUME HOOD MAKE-UP AIR)

A. Design Intent:
1. These VAV boxes provide make-up air and zone temperature control for the spaces that have fume hoods.
2. When the fume hoods are off, the VAV boxes shall be controlled as listed above.
3. When the fume hoods are on, the VAV boxes minimum CFM shall be increased to provide make-up air as listed below:
   a. RTU1-4-H: 400 CFM
   b. RTU1-5-H: 300 CFM

1.11 GARAGE EXHAUST FANS EF-4 & 5

A. Garage Exhaust Fans:
1. Garage 131 is served by EF-5 and an outside air intake louver with a motorized damper.
2. Garage 119 is served by EF-4 and an outside air intake louver with a motorized damper
3. The Level 0 (grade) parking area is exhausted by GEF-101 thru 104 and provided with ventilation air by GSF-101.
4. CO and NO2 sensors shall be installed within both garages.
5. If any CO and/or NO2 sensor detects carbon monoxide above 25 ppm or nitrogen dioxide above 1 ppm within Garage 131, EF-5 shall energize and the outside air damper shall open.
6. If any CO and/or NO2 sensor detects carbon monoxide above 25 ppm or nitrogen dioxide above 1 ppm within Garage 119, EF-4 shall energize and the outside air damper shall open.
7. The fans shall operate for a minimum of 5 minutes (adj).
8. Once the CO levels are below 25 ppm and if the NO2 levels are below 1 ppm, shut off the EFs and close the outside air dampers.
9. Points List:
   a. SA Fan S/S: DO
   b. SA Fan Status: DI
   c. OA Damper Command: DO
d. OA Damper Open Feedback      DI
e. OA Damper Close Feedback      DI
f. CO PPM (each sensor):          AI
g. NO2 PPM (each sensor):         AI

1.12 GENERAL EXHAUST FANS – EF-1, 2, 3, 7 & 8
A. These fans shall operate as per the exhaust fan schedule and shall not be monitored by the BAS.

1.13 SPLIT COOLING UNITS
A. These units shall be provided with local controls and shall not be monitored thru the BAS. Provide field wiring as required.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

END OF SECTION 230993