SECTION 230900

SEQUENCE OF OPERATION FOR HVAC CONTROLS

PART 1 - GENERAL

1.01 DESCRIPTION

A. BAS Contractor shall furnish all labor, materials, equipment, and services necessary to install Temperature Control & Sequence of Operation including all sensors, relays, actuators, and control devices as described herein.

1.02 SUBMITTALS

A. Submit shop drawings for each system (equipment) automatically controlled, containing the following information:
   1. Schematic flow and wiring diagrams showing fans, pumps, coils, dampers, valves, and control devices.
      a. Wiring diagrams are to be point-to-point.
   2. Label each control device with setting or adjustable range of control.
   3. Indicate between factory and field wiring.
   4. Indicate each control panel required, with internal and external wiring clearly indicated.
      a. Provide detail of panel face, including controls, instruments, and labeling.
      b. Include narrative description of sequence of operation and proposed location of any panels.
   5. Valve schedules with size, type, close-offs, failed position and CV calculations.
   6. Damper schedules.
   7. Warranties

B. Include copy of all shop drawings in each Maintenance Manual.

1.03 WARRANTY

A. Control systems specified shall be warranted free from defects for a period of twelve (12) months after final completion acceptance by the Owner.
   1. Control System failures during the warranty period shall be adjusted, repaired, or replaced at no charge or reduction in service to the Owner.
   2. The Contractor shall respond to the Owner's request for warranty service within 24 hours during customary business hours.

PART 2 – SEQUENCE OF OPERATION

2.01 SYSTEM CONTROL / CONTROLLER:

A. Provide devices, hardware, software, controller(s) and control logic as required to accommodate the work of this Section.

B. BAS – Building Automation System: All system setpoints, sensors, equipment, etc. shall be viewable and modifiable thru a web-based system.
   1. Owner's intention is to view the system and make changes to the system, with the ability to "remote-in" from on or off site.
   2. At minimum, graphics shall be provided showing equipment in plan view and one-line diagram fashion. Setpoints and actual readings (of ALL sensors) shall be shown on the graphics.
   3. Alarms shall be sent to email addresses provided by the Owner.

C. Ethernet-based Network Router and/or Network Service Controller(s):
   1. Furnish Ethernet-based Network Server Controllers as required.
   2. These controllers shall connect directly over Ethernet at a minimum of 100mbps, and provide communication to the Standalone Digital Control Units and/or other Input/Output Modules.
   3. Network Server Controllers shall conform to BACnet device profile B-BC.
   4. Network controllers that utilize RS232 serial communications or ARCNET to communicate will not be accepted.
   5. Network Controllers shall be tested and certified by the BACnet Testing Laboratory (BTL) as Network Server Controllers (B-BC).

D. Standalone Digital Control Units (SDCUs):
   1. Provide the necessary quantity and types of SDCUs to meet the requirements of the project for mechanical equipment control.
   2. Each SDCU shall operate completely standalone, containing all of the I/O and programs to control its associated equipment.
   3. Each BACnet protocol SDCU shall conform to the BACnet device profile B-AAC.
   4. BACnet SDCUs shall be tested and certified by the BACnet Testing Laboratory (BTL) as Advanced Application Controllers (B-AAC).

2.02 HIGH TEMPERATURE WATER HEATING SYSTEM:

A. Boilers — BLR-1, 2 and 3
   1. See Section 235216 for boiler controller, controls and sequence of operation.
   2. Provide all necessary control/logic to perform the work of this Section. BAS CONTRACTOR may be required to provide additional control, above and beyond the manufacturer boiler controls, to perform the work of this Section.
   3. Space Heating Sequence of Operation:
      a. See Mechanical One-Line Diagram, Drawing M-601 for additional information.
      b. When outside temperature (T-OA) falls below setpoint (adj.) enable Space Heating Boiler System:
         i. Enable Main Loop Pumps (P-1A or P-1B).
            1.) Pump shall run continuously when enabled.
            2.) Pump shall be speed controlled by an Adjustable Speed Drive (ASD).
         ii. Furnish and install a hydronic loop differential pressure sensor (DP-M1A) at a hydraulically remote location.

1.) Modulate Pump's ASD to maintain differential pressure setpoint (adj.).
2.) Furnish and install a 2-way modulating control valve (CV-M1A).
a.) If pressure at DP-M1 causes pump (P-1A or P-1B) speed to fall below minimum setting (adj.), then modulate CV-M1A as required.

iii. Pump P-1A and P-1B shall lead/lag on a scheduled basis (adj.).
1.) If lead pump does not run when commanded, enable lag pump and alarm.

c. Upon the call for any boiler to come on-line, the circulating pump associated with the boiler (BP-x) shall be enabled and flow shall be made thru a circuit in boiler drawing return water from primary main manifold and returning heated water to primary main manifold downstream.
i. When flow is established, the burner shall fire (modulated) to add heat.
ii. The following is a general firing order scenario.
1.) When T-OA > 60°F (adj.) THEN BLR-1 and 2 in Off Mode.
2.) When T-OA < 60°F (adj.) THEN enable to fire as many boilers as necessary to maintain 130°F (adj.) supply temperature (at T-2).
3.) When T-OA < 45°F (adj.) THEN enable to fire as many boilers as necessary to maintain 140°F (adj.) supply temperature (at T-2).
4.) When T-OA < 30°F (adj.) THEN enable to fire as many boilers as necessary to maintain 160°F (adj.) supply temperature (at T-2).
5.) When T-OA < 20°F (adj.) THEN enable to fire as many boilers as necessary to maintain 180°F (adj.) supply temperature (at T-2).
iii. Boilers BLR-1 and 2 shall lead/lag/lag on a scheduled basis (adj.).

B. Glycol Loop:
1. Provide all necessary control/logic to perform the work of this Section. BAS CONTRACTOR may be required to provide additional control, above and beyond the manufacturer boiler controls, to perform the work of this Section.
2. Glycol Loop Heating Sequence of Operation:
a. See Mechanical One-Line Diagram, Drawing M-601 for additional information.
b. When outside temperature (T-OA) falls below setpoint (adj.) enable Glycol Heating Boiler System:
i. Enable Loop Pumps (P-2A or P-2B).
1.) Pump shall run continuously when enabled.
2.) Pump shall be speed controlled by an Adjustable Speed Drive (ASD).
ii. Furnish and install a hydronic loop differential pressure sensor (DP-M1B) at a hydraulically remote location.
1.) Modulate Pump's ASD to maintain differential pressure setpoint (adj.).
2.) Furnish and install a 2-way modulating control valve (CV-M1B).
a.) If pressure at DP-MB causes pump (P-1A or P-1B) speed to fall below minimum setting (adj.), then modulate CV-M1A as required.
iii. Pump P-2A and P-2B shall lead/lag on a scheduled basis (adj.).
1.) If lead pump does not run when commanded, enable lag pump and alarm.
c. Modulate control valve (CV-G1) as required for the following:
1.) When T-OA > 60°F (adj.) THEN close control valve.
2.) When T-OA < 60°F (adj.) THEN modulate control valve to maintain 125°F (adj.) supply temperature (at T-8).
3.) When T-OA < 45°F (adj.) THEN modulate control valve to maintain 135°F (adj.) supply temperature (at T-8).
4.) When T-OA < 30°F (adj.) THEN modulate control valve to maintain 155°F (adj.) supply temperature (at T-8).
5.) When T-OA < 20°F (adj.) modulate control valve to maintain 175°F (adj.)

supply temperature (at T-8).

2.03 RADIANT IN-FLOOR HOT WATER HEATING SYSTEM:

A. Furnish and install a space temperature Sensor for each space equipped with in-floor heating.
   1. Sensors shall be field located with Owner's Rep.

B. Manifold pumps (P-L-x) shall be enabled when heating system becomes enabled; and shall be disabled when space heating is disabled.
   1. See Typical Manifold Piping Detail.

C. Furnish and install 2-way, modulating, control valves (CV-L-x). Control valves shall modulate as required to maintain room temperature setpoint (adj.).
   1. Hot water supply temperature for in-floor loops (at T-L-x) shall not rise above 120F (adj.).

2.04 SNOW MELT HOT WATER HEATING SYSTEM:

A. For each snow melt loop, furnish and install a snow/ice sensor to be located in the exterior apron/entry pad.
   1. Sensors shall be field located with Owner's Rep. and installed per manuf's requirements.
B. See Part 2.02-B for glycol loop pump operation.
Cs. Manifold pumps (P-L5 and P-L6) shall be enabled when snow melt system becomes enabled; and shall be disabled when snow melt system is disabled.
   1s. Furnish and install 2-way, modulating, control valves (CV-L-5 and CV-L-6). Control valves shall modulate as required to maintain water supply temperature at T-L5A and T-L6A. Maximum hot water supply temperature shall be 130ºF (adj) at sensors T-L5A and T-L6A.
C. When snow or ice is no longer sensed, the system shall be disabled after a period of one (1) hour (adj.).
   1. Disable associated manifold pumps.

D. Alarm if hot water supply temperature at sensors T-L5A or T-L6A rises above 130ºF.

2.05 VARIABLE REFRIGERANT FLOW SYSTEM

A. Manufacturer's control system shall govern the control of the VRF system.
   1. See Section 23 74 19.

B. BAS CONTRACTOR shall furnish all materials and labor associated with the implementation of the manufacturer's control logic.

C. A complete and safe working system shall be provided.

D. Space Temperature:
   1. Furnish and install a programmable thermostat for each VRF Indoor Unit.
   2. Locate thermostat in field where directed by Owner's Rep.
   3. Thermostat shall be fully compatible with VRF system and manuf's control logic.

E. Temperature Setpoints shall be adjustable at BAS.

1. VRF system control logic shall modulate system as required to meet temperature setpoints (adj.).

2.06 HOT WATER HEATERS:

A. CABINET HEATERS — CH-x
   1. Provide space temperature sensor and maintain constant space temperature setpoint (adj.) by cycling fan on/off.
      a. Alarm if space temperature falls below 55°F (adj.).
   2. Locate sensor where field determined with Owner's Rep.
   3. Furnish and install an Aqua-stat, as shown on Cabinet Heater Detail.
      a. Fan shall not be enabled if high temperature water supply is less than 100°F (adj.).

B. UNIT HEATERS — UH-x
   1. Provide space temperature sensor and maintain constant space temperature setpoint (adj.) by cycling fan on/off.
      b. Alarm if space temperature falls below 55°F (adj.).
   2. Locate sensor where field determined with Owner's Rep.
      a. Spaces provide with multiple unit heaters shall average their sensors.
   3. Furnish and install an Aqua-stat, as shown on Unit Heater Detail.
      a. Fan shall not be enabled if high temperature water supply is less than 100°F (adj.).

C. FINNED TUBE RADIATION— FT-x
   1. Furnish and install a 2-way, modulating, control valve for each length of finned tube provided.
      a. See Finned Tube Detail for information.
   2. Provide a space temperature sensor and maintain temperature setpoint (adj.) by modulating the control valve.
      b. Alarm if space temperature falls below 55°F (adj.).
      c. Locate sensor where field determined with Owner's Rep.

FINNED TUBE RADIATION— RP-x
   1. Furnish and install a 2-way, modulating, control valve for each length of radiant heat panel provided.
      a. See Radiant Heat Panel Detail for information.
   2. Provide a space temperature sensor and maintain temperature setpoint (adj.) by modulating the control valve.
      b. Alarm if space temperature falls below 55°F (adj.).
      c. Locate sensor where field determined with Owner's Rep.

2.07 FANS:

A. Exhaust Fan EF-5:
   1. Mechanical Room Exhaust:
      a. Fan shall be controlled as follows:
         i. Furnish and install a space temperature sensor in Mechanical Room.
         ii. When space temperature rises above setpoint (adj), enable exhaust fan and open motorized damper MD-3.
            1.) BAS Contractor to furnish and install actuator.
         iii. When space temperature falls below setpoint (adj), disable exhaust fan and close motorized damper MD-1.
         iv. Exhaust fan and Mechanical and Electrical Room unit heaters shall not be enabled at

same time.

v. If room temperature falls below 40°F (adj.), close MD-3 and alarm at BAS.

B. Exhaust Fan EF-6, EF-7 and EF-8:
   1. Room Exhausts:
      a. Fan shall be enabled on a 24/7 basis.
         i. Alarm at BAS if exhaust fan fails to run.

C. Exhaust Fan EF-3 and EF-4
   1. Intermittent Exhaust:
      a. Fan shall be enabled via a manual switch in room.
         i. BAS Contractor to furnish and install switch, in lockable cover.
      b.

D. Exhaust Fan EF-1-1:
   1. Furnish and install all miscellaneous hardware, control, wiring, etc. necessary for a complete working exhaust system.
      a. Coordinate the components as they pertain to control voltage, etc.
   2. Furnish and install all miscellaneous hardware, control, wiring, etc. necessary for a complete working system.
      a. Coordinate the components as they pertain to control voltage, etc.
   3. Sequence:
      a. Exhaust Fan EF-1-1 shall be enabled and disabled based on carbon monoxide and nitrogen dioxide detection.
      b. Furnish and install a dual, carbon monoxide / nitrogen dioxide system to operate exhaust fan.
         i.) Alarm if exhaust commanded to run does not operate.
      c. When exhaust fan is enabled:
         i.) Open motorized dampers MD-4.
            1.) Provide all necessary control, hardware, software, etc. to integrate logic.
            2.) Provide all required actuators, wiring, etc.
            3.) Provide end switch to prove open.
            4.) Alarm if any damper fails to open.
            5.) Close dampers when fan is disabled.
      d. Carbon Monoxide/Nitrogen Dioxide Gas Detection System
         i. Provide Brasch Gas Detector Model GSE-NCM-LL0 combination NO2 & CO detector to function as a "Stand Alone" gas sensor and ventilation controller. The detector shall consist of remote CO/NO2 sensors (quantities shall be per manuf's recommendation based on coverage areas), control relays and digital control circuitry.
            1.) Acceptable Manufacturers:
               a.) Brasch
               b.) Honeywell
               c.) Navter
         ii. The detector shall be an ETL listed unit containing a control board and sensor board that conforms completely to the UL 3111-1 standard.
         iii. The NEMA 1 enclosure shall be constructed of heavy polycarbonate plastic, which consists of two pieces, cover and chassis. The cover shall close flush with the sides of the box and shall require a special tool to open it. The sensor module shall be protected from damage inside the enclosure and the cover shall contain screened openings to allow proper sensing. The openings shall conform to the UL 3111-1

standard.

iv. The detector shall contain an electro-chemical carbon monoxide (CO) sensor with temperature compensation circuits and an electro-chemical nitrogen dioxide (NO2) sensor.

v. The enclosure shall be provided with four (4), 1/2-inch pre-punched openings for connection of field conduit. The detector shall include factory-installed wiring that exits the enclosure and allows for installation without the detector being opened.

vi. The detector shall be protected against static discharge, excessive electrical noise, and tested for safety in accordance with the UL 3111-1 standard.

vii. The detector shall have a 1/2-inch minimum height, liquid crystal display (LCD) that will continually display the current nitrogen dioxide (NO2) and carbon monoxide (CO) level, in parts per million. The detector shall have a green "power" LED, a yellow "sensor-active" LED, a red "low-alert" LED, a red "high-alert" LED and a red "alarm" LED.

viii. Overcurrent Protection: The detector shall contain a power supply fuse rated for 0.125 amp at 250 VAC, (if 120 VAC powered). Each output relay shall have a fuse rated for 5 amp at 250 VAC. Fuses shall be of the time-lag type.

ix. Switches and Controls: The detector shall provide a 0–10 VDC signal in direct relationship to the nitrogen dioxide (NO2) and carbon monoxide (CO) gas concentrations. The signal shall modulate VFD speed in proportion to NO2 and CO levels. An external push button on the front of the enclosure shall be provided to silence the 106 dB internal alarm. The alarm circuit shall become active again, once the detector is no longer at alarm levels.

x. Output relays providing a normally closed set of contacts for the low-alert and for the alarm shall be provided. These relays shall provide a fail-safe that will automatically activate ventilation equipment upon power loss to the sensor. The low-alert and high-alert relays shall be capable of being configured in the field for a two speed fan control operations. These relays shall be suitable for the connection of 24 VAC, 24 VA inductive circuits.

xi. Switches shall be provided for field adjustment of the gas detection level for the low-alert, and of the on/off time delay for the low-alert and high-alert. Selectable CO detection levels shall range from 20 to 55 ppm and the NO2 detection levels shall range from 0.3 to 4.0 ppm. Selectable time delays shall range from 0 to 7 minutes, in 1 minute increments.

xii. Remote sensors shall be attached by means of a six conductor, shielded cable.

xiii. BAS Contractor shall be responsible to furnish and install the appropriate quantities and locations of NO2 and CO sensors in and around the Apparatus Bay as required to satisfy the manufacturer's requirements.

2.08 ENERGY RECOVERY VENTILATOR: ERV-1

A. General:

1. ERV shall be enabled on a 24/7 basis.
2. ERV shall be used to provide outdoor air and exhaust air to/from the building. In general, air will be discharged at 2°F (adj.) above return air temperatures during the heating season; and 2°F (adj.) below return air temperature during the cooling season.
   a. ERV will be equipped with a hot gas reheat coil. If space humidity or supply air humidity rises above setpoint(s), enable dehumidification mode per manufacturer's control logic.
      i. Furnish and install a space humidity sensor (in community room), an in-duct exhaust air humidity sensor and an in-duct supply air humidity sensor.

3. The ERV shall be equipped with an enthalpy wheel, a supply fan and an exhaust fan.
4. Provide DDC controls to enable, disable and monitor the ERVs and provide occupied/unoccupied control.

B. ERV shall be factory equipped with:
1. Supply Fan
   a. with factory-mounted adjustable speed drive
2. Exhaust Fan
   a. with factory-mounted adjustable speed drive
3. Enthalpy Wheel
4. Supply Air Dampers
   a. with factory-mounted DDC actuator
5. Outdoor Air/Return Air Dampers
   a. with factory-mounted DDC actuator
6. Filter Section
7. Air-Cooled Cooling Section
8. Hot Gas Reheat Section
9. Hot Water Coil Section

C. SEQUENCE OF OPERATION:
1. When Enabled:
   a. The supply fan and exhaust fan shall be enabled and run continuously, motorized dampers shall be opened, and enthalpy wheel shall rotate (unless logic calls for it to be stopped).
      i. Leaving air temperature (LAT) shall be sensed by an in-line air stream temperature sensor.
   b. During occupied mode, supply airflow must not fall below outdoor airflow setpoint.
2. Zone Setpoint Adjust:
   a. The Building operator shall be able to adjust the zone temperature heating and cooling setpoints through ERV controller.
3. Zone Optimal Start:
   a. The unit shall use an optimal start algorithm for morning start-up.
   b. This algorithm shall minimize the unoccupied warm-up or cool-down period while still achieving comfort conditions by the start of scheduled occupied period.
4. Zone Unoccupied Override:
   a. A timed local override control shall allow Building operator to override the schedule and place the unit into an occupied mode for an adjustable period of time.
   b. At the expiration of this time, control of the unit shall automatically return to the schedule.
5. Supply Fan:
   a. The supply fan shall run anytime the unit is commanded to run, unless shutdown on safeties.
   b. To prevent short cycling, the supply fan shall have a user definable (adj.) minimum runtime.
   c. Alarms shall be provided as follows:
      i. Supply Fan Failure: Commanded on, but the status is off.
      ii. Supply Fan In Hand: Commanded off, but the status is on.
      iii. Supply Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).
6. Supply Air Duct Static Pressure Control:

a. The controller shall measure duct static pressure and shall modulate the supply fan VFD speed to maintain duct static pressure setpoint (adj.).
b. The supply fan VFD speed shall not drop below 30% (adj.).
c. Alarms shall be provided as follows:
    i. High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than setpoint.
    ii. Low Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) less than setpoint.
    iii. Supply Fan VFD Fault
d. Furnish and install duct static pressure sensors as required.

7. Exhaust Fan:
    a. The exhaust fan shall run anytime the unit is commanded to run, unless shutdown on safeties.
    b. To prevent short cycling, the exhaust fan shall have a user definable (adj.) minimum runtime.
    c. Alarms shall be provided as follows:
        i. Exhaust Fan Failure: Commanded on, but the status is off.
        ii. Exhaust Fan In Hand: Commanded off, but the status is on.
        iii. Exhaust Fan Runtime Exceeded: Status runtime exceeds a user definable limit (adj.).
8. Exhaust Air Duct Static Pressure Control:
    a. The controller shall measure duct static pressure and shall modulate the exhaust fan VFD speed to maintain duct static pressure setpoint (adj.).
    b. The exhaust fan VFD speed shall not drop below 30% (adj.).
    c. Alarms shall be provided as follows:
        i. High Supply Air Static Pressure: If the exhaust air static pressure is 25% (adj.) greater than setpoint.
        ii. Low Supply Air Static Pressure: If the exhaust air static pressure is 25% (adj.) less than setpoint.
        iii. Exhaust Fan VFD Fault
    d. Furnish and install duct static pressure sensors as required.
9. Economizer Mode:
    a. When outdoor air temperatures permit, the enthalpy wheel shall be stopped to allow for free-cooling.
10. Dirty Filters:
    a. Measure pressure differential across the filters; and signal shall be sent to the BAS to indicate the alarm condition.
11. Wheel Rotation Sensor:
    a. Unit shall automatically shut down if the heat exchanger wheel stops rotating (unless in free-cooling, defrost mode or unoccupied condition).
    b. Signal shall be sent to the BAS to indicate the alarm condition.
12. Defrost:
    a. Defrost capability shall be time-based, temperature initiated (-5ºF).
    b. Recirculated strategy whereas the supply fan circulates air and exhaust fan de-energizes.
13. Motorized Dampers:
    a. All motorized dampers shall completely close when ERV is not in operation and completely open when the unit is in operation.
    b. Note that outdoor air damper shall be mounted external to ERV. Operate damper as an integral part of ERV.
14. Timed Override:
    a. When a timed override is initiated by the user, the unit shall return to its user defined normal occupied mode for the user determined period of time (adj.).

15. Fire Shutdown:
    a. The unit shall shut down in response to smoke detection in the return air ductwork.
    b. Furnish and install a "listed" smoke detector in each return and/or supply duct to signal a contact closure to the BAS indicating the presence of a fire or other emergency condition.
16. Duct Static:
    a. A manual-reset, discharge air, high static safety shall disable fans and input to the controller upon sensing a static pressure higher than the normal operating setpoint.
    b. A manual-reset, outside air, low static safety shall disable fans and input to the controller upon sensing a static pressure lower than the normal operating setpoint.
    c. A manual-reset, return air, low static safety shall disable fans and input to the controller upon sensing a static pressure lower than the normal operating setpoint.
    d. Contractor to furnish and install in-duct static pressure sensors in supply and exhaust ductwork. Location shall be per manuf's recommendations.
17. Heating:
    i. When outdoor air temperature falls below 60°F (adj.), modulate two-way control valve as required to maintain space temperature setpoint at 65°F (adj).
    ii. When outdoor air temperature rises above 60°F (adj.) close two-way control valve.
    iii. Furnish and install a freeze-stat sensor serpentined on leaving air side of heating coil. If leaving air temperature falls below 40°F (adj):
        a.) Alarm at BAS and provide audible alarm in Apparatus Bay.
        b.) fully open two-way valve.
        d.) disabled ERV-1.
18. Provide actuated control for motorized dampers MD-1A/1B, 2A/2B, 3A/3B, 4A/4B. Fully open and close when occupancy is sensed in associated room. Furnish and install occupancy sensor for each motorized damper where directed in field.

2.09 HEAT RECOVERY VENTILATOR:

A. See Section 237202 for additional information.

B. Install manufacturer-provided controller where directed by Owner's Representative.

C. Provide all necessary wiring, relays, connections and accessories.

D. Sequence – HRV-1

1. Heat Recovery Ventilator shall be enabled and operate continuously 24/7 (adj.).
    a. Open motorized dampers MD-6 and MD-7 when Ventilator is enabled and close motorized dampers when Ventilator is disabled.
2. Heat Recovery Ventilator shall be controlled per manufacturer's control logic.
3. Furnish and install space temperature in Apparatus Bay, where directed in field by Owner's Rep. If space temperature falls below 50-deg F (adj.) for 15-minutes (adj.):
    a. Alarm BAS and sound audible Alarm in Apparatus Bay.
    b. Disable Heat Recovery Ventilator and close motorized dampers MD-6 and MD-7.

4. HRV-1 shall supply tempered air as follows:
    a. BAS Contractor shall furnish and install a discharge air sensor downstream of heating coil (HWC-1). BAS Contractor shall furnish and install a room temperature sensor in apparatus bay.

b. Heating:
   i. See In Duct Heating Coil Piping Detail.
   ii. When outdoor air temperature falls below 60°F (adj.), modulate two-way control valve as required to maintain space temperature setpoint at 65°F (adj).
   iii. When outdoor air temperature rises above 60°F (adj.) close two-way control valve.
   iv. Furnish and install a freeze-stat sensor serpentined on leaving air side of heating coil. If leaving air temperature falls below 40°F (adj):
      a.) Alarm at BAS and provide audible alarm in Apparatus Bay.
      b.) fully open two-way valve.
      d.) disabled HRV-1.

2.10 CEILING FANS:

A. See Section 233426 for additional information.

B. Install manufacturer-provided controller where directed by Owner's Representative.

C. Provide all necessary wiring, relays, connections and accessories.

D. All ceiling fans shall be enabled/disabled/controlled together at a single station in Apparatus Bay. Location shall be determined in field with Owner's Rep.

2.11 VEHICAL EXTRACTION SYSTEM:

A. Vehicle Extraction System and associated Exhaust Fan shall be enabled and disabled via a manufacturer furnished, remote, wall controller.

B. BAS Contractor shall provide all necessary controls to extend controller to BAS system.

C. When the vehicle extraction system is enabled, open motorized damper MD-4.
Close motorized damper MD-4 when the vehicle extraction system is disabled.
   1. If Apparatus Bay space temperature falls below 50°F (adj.), close motorized damper.
   2. Alarm is space temperature falls below 40F (adj.).

2.12 DOMESTIC WATER HEATERS:

A. Water Heater: WH-1
   1. Water Heater's integral setpoint shall be set to maintain 140F storage temperature:
      a. Thermostatic Mixing Valve (TMV-1) shall be arranged to deliver 110F domestic hot water supply.
   2. Recirculation Pump: RCP-1:
      a. Pump shall operate to maintain domestic water return temperature of 110°F (adj.).
   3. Recirculation Pump: RCP-2:
      a. Pump shall operate to maintain domestic water return temperature of 140°F (adj.).

PART 3 - EXECUTION

3.01 CLEANUP

A. At the completion of the work, all equipment pertinent to this contract shall be checked and thoroughly cleaned, and all other areas shall be cleaned around equipment provided under this contract.

3.02 WIRING, CONDUIT, AND CABLE.

A. See Section 271500, Horizontal Cabling for information.

3.03 INSTALLATION PRACTICES FOR FIELD DEVICES

A. Well-mounted sensors shall include thermal conducting compound within the well to insure good heat transfer to the sensor.

B. Actuators shall be firmly mounted to give positive movement and linkage will be adjusted to give smooth continuous movement throughout 100 percent of the stroke.

C. Relay outputs shall include transient suppression across all coils. Suppression devices shall limit transients to 150% of the rated coil voltage.

D. Water line mounted sensors shall be removable without shutting down the system in which they are installed.

E. For duct static pressure sensors, the high pressure port shall be connected to a metal static pressure probe inserted into the duct pointing upstream. The low pressure port shall be left open to the plenum area at the point that the high pressure port is tapped into the ductwork.

F. For building static pressure sensors, the high pressure port shall be inserted into the space via a metal tube. Pipe the low pressure port to the outside of the building.

G. Enclosures
   1. For all I/O requiring field interface devices, these devices where practical shall be mounted in a field interface panel (FIP). The Contractor shall provide an enclosure which protects the device(s) from dust, moisture, conceals integral wiring and moving parts.
   2. FIPs shall contain power supplies for sensors, interface relays and contactors, safety circuits, and I/P transducers.
   3. The FIP enclosure shall be of steel construction with baked enamel finish, NEMA 1 rated with a hinged door and keyed lock. The enclosure shall be sized for twenty percent spare mounting space. All locks shall be keyed identically.
   4. All wiring to and from the FIP shall be to screw type terminals. Analog or communications wiring may use the FIP as a raceway without terminating. The use of wire nuts within the FIP is prohibited.
   5. All outside mounted enclosures shall meet the NEMA-4 rating.
   6. The wiring within all enclosures shall be run in plastic track. Wiring within controllers shall be wrapped and secured.

H. Identification
   1. Identify all control wires with labeling tape or sleeves using either words, letters, or numbers that can be exactly cross-referenced with as-built drawings.
   2. All field enclosures, other than controllers, shall be identified with a bakelite nameplate. The lettering shall be in white against a black or blue background.
   3. Junction box covers shall be marked to indicate that they are a part of the BAS system.
   4. All I/O field devices (except space sensors) that are not mounted within FIP's shall be identified with name plates.
   5. All I/O field devices inside FIP's shall be labeled.

I. Location
   1. Space humidity or temperature sensors shall be mounted away from machinery generating heat, direct light and diffuser air streams.
   2. Outdoor air sensors shall be mounted on the north building face directly in the outside air. Install these sensors such that the effects of heat radiated from the building or sunlight is minimized.
   3. Field enclosures shall be located immediately adjacent to the controller panel(s) to which it is being interfaced.

3.04 SYSTEM ACCEPTANCE TESTING

A. All application software shall be verified and compared against the sequences of operation. Control loops will be exercised by inducing a setpoint shift of at least 10% and observing whether the system successfully returns the process variable to setpoint.

B. Test each alarm in the system and validate that the system generates the appropriate alarm message, that the message appears at all prescribed destinations (workstations or printers), and that any other related actions occur as defined (i.e. graphic panels are invoked, reports are generated, etc.). Submit a Test Results Sheet to the owner.

C. Perform an operational test of each unique graphic display and report to verify that the item exists, that the appearance and content are correct, and that any special features work as intended. Submit a Test Results Sheet to the owner.

D. Perform an operational test of each third party interface that has been included as part of the automation system. Verify that all points are properly polled, that alarms have been configured, and that any associated graphics and reports have been completed. If the interface involves a file transfer over Ethernet, test any logic that controls the transmission of the file, and verify the content of the specified information.

3.05 TRAINING

A. Upon completion of the project and commissioning, the BAS Contractor shall provide a minimum of forty (40) hours of on-site training.

END OF SECTION 230900