SECTION 23 09 93

SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

BUILDING AUTOMATION SYSTEM/CONTROLS PACKAGE PURCHASED UNDER SEPARATE CONTRACT. CONTRACTOR SHALL PROVIDE ALL CONTROLS AND INTERCONNECTING WIRING FOR THE VARIABLE REFRIGERANT FLOW (VRF) SYSTEM AS REQUIRED IN THE SPECIFICATIONS. ALL HEAD-END EQUIPMENT, CONTROLLERS, WIRING, LABOR, AND SOFTWARE REQUIRED TO INTEGRATE THE VRF SYSTEM AND PROVIDE CONTROLS FOR THE ENERGY RECOVERY VENTILAOTRS (ERV) AND PACKAGED ROOF-TOP MOUNTED AIR HANDLING UNITS (RTU) SHALL BE PROVIDED UNDER SEPERATE CONTRACT.

1.01 PART 1 GENERAL

1.02 This section defines the general operating parameters for the Buildign Automation System purchased under separate contract by the Owner. It further defines the expected operating parameters of the VRF system as defined in specificaiton section 23 81 29.

1.03 SECTION INCLUDES

A. This section defines the manner and method by which controls function. Requirements for each type of control system operation are specified. Equipment, devices, and system components required for control systems are specified in other sections.

B. Sequence of operation for:
   1. Packaged Rooftop Outdoor Air Units with Energy Recovery
   2. Kitchen Exhaust Hoods / Kitchen Ventilation Systems
   3. Variable Refrigerant Flow (VRF) Heat Pump Systems
   4. Radiation and convectors.
   5. Energy Recovery Ventilators/Supply Air Units

1.04 RELATED SECTIONS

A. Section 23 09 23 - Direct-Digital Control System for HVAC.

B. Section 23 09 13 - Instrumentation and Control Devices for HVAC.

C. Section 26 27 17 - Equipment Wiring: Electrical characteristics and wiring connections.

1.05 SYSTEM DESCRIPTION

A. This Section defines the manner and method by which controls function. Requirements for each type of control system operation are specified. Equipment, devices, and system components required for control systems are specified in other Sections.

1.06 SUBMITTALS

A. See Section 01 30 00 - Administrative Requirements, for submittal procedures.

B. Sequence of Operation Documentation: Submit written sequence of operation for entire HVAC system and each piece of equipment.
   1. Preface: 1 or 2 paragraph overview narrative of the system describing its purpose, components and function.
   2. State each sequence in small segments and give each segment a unique number for referencing in Functional Test procedures; provide a complete description regardless of the completeness and clarity of the sequences specified in the contract documents.
   3. Include at least the following sequences:
      a. Start-up.

b. Warm-up mode.
c. Normal operating mode.
d. Unoccupied mode.
e. Shutdown.
f. Capacity control sequences and equipment staging.
g. Temperature and pressure control, such as setbacks, setups, resets, etc.
h. Detailed sequences for all control strategies, such as economizer control, optimum start/stop, staging, optimization, demand limiting, etc.
i. Effects of power or equipment failure with all standby component functions.
j. Sequences for all alarms and emergency shut downs.
k. Seasonal operational differences and recommendations.
l. Interactions and interlocks with other systems.

4. Include initial and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment.
5. For packaged controlled equipment, include manufacturer's furnished sequence of operation amplified as required to describe the relationship between the packaged controls and the control system, indicating which points are adjustable control points and which points are only monitored.
6. Include schedules, if known.

C. Control System Diagrams: Submit graphic schematic of the control system showing each control component and each component controlled, monitored, or enabled.
1. Label with settings, adjustable range of control and limits.
2. Include flow diagrams for each control system, graphically depicting control logic.
3. Include the system and component layout of all equipment that the control system monitors, enables or controls, even if the equipment is primarily controlled by packaged or integral controls.
4. Include draft copies of graphic displays indicating mechanical system components, control system components, and controlled function status and value.
5. Include all monitoring, control and virtual points specified in elsewhere.
6. Include a key to all abbreviations.

D. Points List: Submit list of all control points indicating at least the following for each point.
1. Name of controlled system.
2. Point abbreviation.
3. Point description; such as dry bulb temperature, airflow, etc.
4. Display unit.
5. Control point or setpoint (Yes / No); i.e. a point that controls equipment and can have its setpoint changed.
6. Monitoring point (Yes / No); i.e. a point that does not control or contribute to the control of equipment but is used for operation, maintenance, or performance verification.
7. Intermediate point (Yes / No); i.e. a point whose value is used to make a calculation which then controls equipment, such as space temperatures that are averaged to a virtual point to control reset.
8. Calculated point (Yes / No); i.e. a “virtual” point generated from calculations of other point values.

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

1.07 QUALITY ASSURANCE

A. Design system under direct supervision of a Professional Engineer experienced in design of this Work and licensed in DE.

PART 2 PRODUCTS - NOT USED

PART 3 EXECUTION

3.01 General System Design and Operation Standards

A. The BAS shall control the mechanical systems within the site based upon a variable refrigerant flow (VRF) heat pump system with central energy recovery ventilators supplying outdoor air to the terminal units. Large assebly spaces are served by packed DX cooling / gas fired heating rooftop units with energy recovery and hot-gas reheat-basd dehumidification controls.

B. Each unit shall be controlled by an individual DDC Controller and all required sensors, control valves, and appurtenances required to complete the sequence of operation. Units shall include occupied/unoccupied control, night-setback, morning warm-up/cool-down, and enthalpy-based economizer functions.

3.02 Kitchen Exhaust Hoods / Kitchen Make-Up Air Units

A. Exhaust fans servince Hoods shall be controlled manually via a hood-mounted control system.

B. Provide a current sensor for each fan (supply and exhaust) to show operational status.

C. The following items shall be displayed at the Operator's Terminal:
   1. Operational status of fan via current sensor.

3.03 Variable Refrigerant Volume Heat Pump Systems

A. The variable refrigerant split system shall have a BAS DDC interface wired to the manufacturer factory central system controller and central outdoor air damper (as applicable) to provide operation, configuration, and monitoring of the system. The manufacturer factory central controller shall operate in BACnet protocol, and be connected to manufacturer factory space temperature sensors as specified.

B. Sequence of operation:
   1. Cooling Mode: Cooling mode shall be selected based on outdoor air temperatures or manually enabled or scheduled from the workstation. During the programmed occupied mode, the supply fan shall run continuously with the outside air damper open to the minimum position. On a rise in space temperature above the setpoint (75 degrees, adjustable), the manufacturer central controller shall energize the central compressor to provide cooling. The internal capacity control valve in the evaporator unit shall modulate to control the flow of refrigerant to maintain space temperature. On a fall in space temperature the refrigerant capacity control valve shall modulate closed.

2. Heating Mode: Heating mode shall be selected based on outdoor air temperatures or manually enabled or scheduled from the workstation. During the programmed occupied mode, the supply fan shall run continuously with the central outside air damper open to the minimum position. On a drop in space temperature below the setpoint (68 degrees, adjustable), the manufacturer central controller shall energize the central compressor to with the requisite reversing valve to provide heating to the evaporator unit as required. The internal capacity control valve in the evaporator unit shall modulate to control the flow of refrigerant to maintain space temperature. On a fall in space temperature the refrigerant capacity control valve shall modulate closed.
3. The following items shall be accessible and displayed at the Operator's Terminal:
   a. Commanded status of outdoor air damper.
   b. Space temperature setpoint at each fan-coil unit (user adjustable).
   c. Actual space temperature of each fan-coil unit space.
   d. Operational status of each fan-coil unit (heating, cooling, off, user adjustable).
   e. Factory error codes from each unit.
   f. Remote space temperature sensor override for each fan-coil unit (user adjustable to limit temperature adjustment range, heat/cool selection, fan speed).
   g. Energy Saving Command
   h. Compressor Status
   i. Accumulated Power Consumption

C. Each terminal unit (fan coil) shall be controlled by the factory-provided wall-mounted controller. The controller shall be capable of allowing space temperature adjustment of +1 / -1 degrees (user adjustable).

3.04 Packaged Rooftop Units with Natural Gas Heat

A. Each unit shall be controlled by an individual DDC Controller. The DDC Controller shall be wired to a space temperature sensor, space-level CO2 sensor, discharge air temperature sensor, return air temperature sensor, space differential pressure sensor, damper motors, and the contacts to the factory-mounted unit control system controlling the compressor(s), hot-gas bypass, hot-gas reheat, and gas train combustion equipment.

B. Cooling Mode:
1. During the programmed occupied mode, the supply fan, return fan, and energy recovery wheel shall run continuously with the outside air damper open to the minimum position (10% outdoor air, adjustable). The amount of outside air will be increased above the minimum setting on a rise in the space CO2 level above the setpoint of 1000 PPM (adjustable) up to the code required minimum O/A (see schedule). On a return to the CO2 level setpoint the reverse shall occur. On a rise in temperature above the programmed cooling setpoint (adjustable), the following shall occur, in order, and to the extent necessary:
   a. The DX cooling system shall be engaged. The compressors and hot-gas bypass system shall modulate as necessary to meet the cooling demands of the space and the discharge air temperature setpoint (adjustable).
   b. When dehuminidifcation is required as sensed by the factory-provided humidistat (setpoint, 60% RH, adjustable), the hot-gas reheat system will be engaged and follow the factory-programmed sequence.
   c. Upon a fall in space temperature the reverse shall occur.
2. The factory-provided VFD shall modulate the speed of the energy recovery wheel as required to maintain optimal performance as the outdoor air levels vary with the CO2 levels within the space.
3. For units equipped with an outdoor air economizer: The DDC Controller shall receive input from the Global Enthalpy Sensor. If the enthalpy of the outdoor air is lower than

the defined minimum level (user adjustable) the economizer sequence shall be activated upon a call for cooling. This sequence shall include opening the outside air damper up to 100%, opening the outside air. This shall be done for each unit that is in operation. The outside air damper shall never close past the minimum position during the occupied period.

C. Heating Mode:
   1. During the programmed occupied mode, the supply fan and return fan (if equipped) shall run continuously with the outside air damper open to the minimum position (10% outdoor air, adjustable). The amount of outside air will be increased above the minimum setting on a rise in the space CO2 level above the setpoint of 1000 PPM (adjustable). On a return to setpoint the reverse shall occur. On a drop in temperature below the programmed heating setpoint, the following shall occur, in order, and to the extent necessary:
      a. The factory-mounted controller shall command the gas-train to ignite and provide heating. The gas-train shall modulate from it's lowest to highest setting depending on demand.
      b. When dehuminidifcation is required as sensed by the factory-provided humidistat (setpoint, 60% RH, adjustable), the hot-gas reheat system will be engaged and follow the factory-programmed sequence.
      c. Upon a rise in space temperature the reverse shall occur.
   2. The factory-provided VFD shall modulate the speed of the energy recovery wheel as required to maintain optimal performance as the outdoor air levels vary with the CO2 levels within the space.

D. Unoccupied Mode:
   1. During the programmed un-occupied mode, the supply fan, compressor, gas train, and dampers for shall be cycled / modulated to maintain the un-occupied setpoints (55 degrees in Heating mode, 80 degrees in Cooling mode, both adjustable). Unless required for economizer cycle, the outside air damper shall remain closed.

E. All setpoints and shall be adjustable at the BAS workstation.

F. Provide a current sensor on one phase of power feeding each supply fan, exhaust fan, heat wheel, and compressor for status indication at the Operator's Terminal.

G. If the discharge temperature fails to rise to a programmed minimum temperature during a call for heating; a low temperature alarm shall be activated at the Operator's Terminal. If the discharge temperature fails to fall to a programmed minimum temperature on a call for mechanical cooling, a high temperature alarm shall be activated at the Operator's Terminal.

H. The following items shall be displayed at the Operator's Terminal:
   1. Space temperature.
   2. Space temperature setpoint.
   3. Space humidity.
   4. Space humidity setpoint.
   5. Low Space temperature alarm.
   6. High Space temperature alarm.
   7. Discharge air temperature.
   8. Discharge air temperature setpoint.
   9. Return air temperature.
   10. Outside air temperature, humidity and enthalpy.
   11. Economizer enthalpy setpoint.
   12. Space CO2 level.
   13. Space CO2 level setpoint.

14. Space high CO2 level alarm: “1500 PPM”, adjustable.
15. Supply fan operational status via current sensor.
16. Commanded status of supply fan.
17. Exhaust fan operational status via current sensor.
18. Commanded status of exhaust fan.
19. Heat Wheel operational status via current sensor.
20. Commanded status of heat wheel.
21. Commanded status of compressor(s).
22. Commanded status of gas-train.
23. Commanded position of dampers.
24. Diagram showing the layout of the unit with major components and dynamic temperatures shown where temperature sensors exist in the system.

3.05 Electric Resistance Radiant and Convective Heating Units

A. The electric-resistance radiant and convective heating units shall be controlled by a self contained, unit mounted controller with remote sensing element.

3.06 Supply Air Units and Energy Recovery Ventilators (ERV)

A. Supply air units and ERV's shall be scheduled for occupied and unoccupied cycles based on an operator adjustable time schedule. Units may also be manually enabled and disabled at the operator workstation. Fan status shall be monitored by the BAS via the fans current sensing relay.

B. The variable frequency drive shall modulate to maintain a defined static pressure as determined by the balancer to maintain proper flow rates of outdoor air.

C. When any heat pump in the area served be the heat recovery unit is in the occupied mode the unit shall be energized.
   1. The unit exhaust and outside air isolation dampers shall open.
   2. Provide proof of airflow for each fan and provide fan failure alarms.
   3. Provide temperature indication of the supply and exhaust inlet and leaving air.
   4. For units over 2,000 cfm a duct smoke detector shall be provided by the electrical contractor. Provide the interlock wiring to shut down the units upon activation.
   5. The electric heating coil shall be energized when required to maintain a minimum discharge air (supply air) temperature of 60 degrees to the units.

D. The following items shall be displayed at the operators workstation:
   1. Discharge temperature.
   2. Return air temperature.
   3. Outside air temperature, humidity and enthalpy.
   4. Fan operational status via current sensor.
   5. Commanded status of fan.
   6. Commanded status of heating coils.
   7. Commanded status of gas-train.
   8. Commanded position of dampers.
   9. Diagram showing the layout of the unit with major components and dynamic temperatures shown where temperature sensors exist in the system.

E.

END OF SECTION