

SECTION 23 09 93 - SEQUENCE OF OPERATIONS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the contract, including general and supplementary conditions and division 1 specification sections, apply to this section.

1.2 SUMMARY

- A. This Section includes control sequences for HVAC systems, subsystems, and equipment.
- B. Related Sections Include The Following:
 - 1. Division 23 Section "HVAC Instrumentation And Controls" For Control Equipment And Devices And Submittal Requirements.

1.3 Definitions

- A. Retain acronym and abbreviation that remain after this section has been edited.
- B. ATC: Automatic Temperature Control.
- C. BMS: Building Management System.
- D. CFM: Cubic Feet Per Minute.
- E. DDC: Direct-digital controls.
- F. FAS: Fire Alarm System.
- G. HVAC: Heating, Ventilating, and Air Conditioning.
- H. MER: Mechanical Equipment Room.
- I. AHU: Air Handling Unit.
- J. VAV: Variable air volume.
- K. VFD: Variable Frequency Drive.

1.4 GENERAL

- A. Any safety shutdown shall allow for an automatic local reset and a manual remote reset and restart from the BMS system. All safety devices shall be hardwired to the starter and shall have a second contact for monitoring via the BMS.

- B. All setpoints including setpoints internal to control algorithms shall be adjustable from all BMS operator interfaces.
 - C. All alarm points shall be annunciated at the BMS audibly and visually.
 - D. All controllers shall incorporate proportional-integral-derivative control loops.
 - E. All points for a specific mechanical system shall be connected to and controlled by the same DDC controller unless otherwise specified. For example, it is not acceptable to control a supply fan with one DDC controller located at a motor control center and to control the rest of the air-handling unit points with a DDC controller located at the air-handling unit.
 - F. When there is a building wide emergency condition, including but not limited to, fire alarm, loss of power, switchover from normal power to emergency power, switchover from emergency power to normal power, etc., all BMS alarms (i.e., fan failure, pump failure, etc.) due to these conditions shall be inhibited. All alarms indicating the type of emergency condition or reason for the emergency condition shall remain active.
 - G. The BMS operating system and software shall be upgraded to the latest edition available on all operator workstations and operator interface devices.
 - H. Submit on wiring diagrams and control diagrams for all equipment listed herein regardless of whether the controls are packaged, provided by others, etc. It is the intent of this specification that this Contractor shall provide the Owner with complete and final O & M manuals that include controls for ALL equipment regardless of who provided it.
 - I. All points required by the sequence of operation including but not limited to the operator interface points listed in the sequences of operation below, as well as all of the points' associated values, shall be available to the BMS operators on all operator workstations and all operator interface devices as part of a graphical display that graphically depicts the mechanical system controlled.
 - J. The installed BMS shall have dedicated, LAN based communication buses independent of the building IT network for both primary and secondary buses.
 - K. All valves, dampers, controllers, control devices, etc. exposed to outside air conditions shall be specifically designed for outside air conditions including, but not limited to, NEMA 4 enclosures, weatherproof enclosures, and all other weather precautions recommended by the manufacturer.
 - L. The BMS contractor shall furnish, install, and wire a UPS for every primary control panel and every operator workstation.
- 1.5 AUTOMATIC RESTART SEQUENCE
- A. The BMS contractor shall submit an automatic restart sequence of operation that prioritizes the loads to be restarted, in order of importance, when a changeover in power occurs, either from normal power to emergency power or from emergency

power to normal power, and when there is more than one piece of mechanical equipment to start at the same time (e.g., at the beginning of a normally scheduled occupied cycle). The automatic restart sequence of operation shall also show the time delays between the startup of each piece of mechanical equipment.

- B. Simultaneous starting of motors shall be prevented by a sequential start program in the DDC system. This program shall also provide sequential restart after power failure of motors that were running prior to power failure.
- C. Software time delay relays shall be provided in the DDC system to allow fan motors to cool down before restarting. Motors shall have both a minimum interval time (between consecutive starts) and a minimum off time (between start and stop). The time periods shall be based on motor HP per the following table. Time periods are in minutes.

Motor Horsepower	¼-10	10-20	20-50
Minimum Interval Time	10	20	30
Minimum Off Time (adj.)	3	5	7

- D. Automatic restart of fans after a safety shutdown trip shall be software prohibited through the de-energization of the remote start/stop contact. Fan restart shall be manually initiated by the operator either locally or remotely through a computer workstation after resolving the cause for shutdown.
- E. Operator Workstation: Display the following data:
 - 1. Individual minimum interval time for each piece of mechanical equipment.
 - 2. Individual minimum off time for each piece of mechanical equipment.
 - 3. Individual motor horsepower.
 - 4. Individual restart delay for each piece of mechanical equipment.

1.6 SEQUENCE OF OPERATION

- A. Air Handling Units- (AHU 146, 147 and 148)

- 1. General
 - a. The BMS contractor shall furnish, mount and wire power to all control panels from the electrical contractor provided circuit board. The BMS contractor shall wire with power all fire/smoke dampers and smoke dampers. The BMS contractor is also responsible for all fan interlocks. The fire/smoke and smoke dampers shall be provided and installed by the mechanical contractor.

2. Safeties

- a. The supply and return smoke detector shall stop all supply and return fans upon the presence of smoke through the DDC system from a signal from the associated duct smoke detectors.
- b. High discharge air pressure switches one located downstream of the supply fan and upstream of the closest damper and one located downstream of the return fan and upstream of the closest dampers shall stop the supply and associated return air fans when duct pressure exceeds design. The supply and return fans shall remain off until the air pressure switch is manually reset.
- c. Low discharge air pressure switches one located upstream of the supply fan and downstream of the closest damper and one located upstream of the return fan and downstream of the closest damper shall stop the supply fan and associated return air fan when pressure exceeds design. The supply and return fans shall remain off until the air pressure switch is manually set.
- d. A freeze-stat installed downstream of the preheat coil and upstream of the cooling coil shall de-energize the supply and associated return fans upon sensing a temperature below 40°F (adj.). The preheat coil 2-way valve shall allow 100% flow through the coil.
- e. A differential pressure sensor shall monitor the pressure across each filter bank. A high pressure alarm shall annunciate at the BMS when the high filter differential pressure setpoint is surpassed.
- f. A high humidity limit sensor with auto-reset capability shall modulate the humidifier to limit the supply air humidity to 90% RH (adj).

3. Enabled Mode

- a. The air-handling units are intended to run 24/7 and shall be started from the BMS.
- b. Upon a command to start, all associated two position dampers (i.e.; return air damper, smoke dampers, fire/smoke dampers, etc.) shall open and be proven by end switch. The BMS contractor shall install a time delay relay which shall delay the supply and return fan starter 30secs (adj.) before energizing. The supply fans and return fans shall start in parallel at minimum speed. After a 30 second delay the supply fans shall ramp up in parallel to maintain static pressure setpoint in the supply air duct.
- c. A normally closed two position automatic damper shall be installed in a cross tie on both the supply and return ducts as shown on the floor plans between AHU 147 and AHU 146. The purpose of the cross tie is an emergency back-up should a unit fail. The cross tie damper shall be

manually enabled from the controls computer and shall be monitored via an end switch.

- d. For AHU 147 and 148, the speed of the return fan VFD shall be controlled to track the supply fans via airflow stations in the supply and return fan inlets to maintain a fixed CFM differential as indicated on the airflow tracking schedule. For AHU 146 the return fan shall control to maintain the static pressure setpoint in the return air duct.
- E. The return air and exhaust air dampers shall modulate, the return air damper closing and the exhaust air damper opening, so as to maintain the minimum outdoor air quantity through the minimum outdoor air damper airflow station.

Air Tracking Schedule

AHU	S. A. CFM	R.A. CFM	Min O.A. CFM
AHU-147	11,300 Phase-1	9,100 Phase-1	4,000 Phase-1
AHU-148	36,000	14,400	21,600

4. Discharge Air Temperature Control:

- a. The AHU shall have an initial discharge air temperature setpoint of 60 degrees F. Cooling requests from the space VAV box controllers shall reduce this initial discharge air setpoint downward to 55 degrees F, if additional cooling is required in the spaces. Discharge air setpoint shall also reduce downward as required to maintain 50% R.H. in the space as sensed by a return air humidity sensor located in the general return main. For AHU-146 the D.A.T Setpoint shall reduce downward as required to maintain 50% R.H. as sensed by any O.R. room humidistat. The D.A.T. shall have a minimum setpoint of 50 degrees F and a maximum setpoint of 65 degrees F, based on the VAV box controller's demands.
- b. On a call for cooling, if the outdoor air enthalpy is less than the return air enthalpy, the return air and relief air dampers shall modulate accordingly, subject to a 45 degree F mixed air low limit, so as the maintain discharge air setpoint.
- c. If economizer cooling is not available or can not meet the cooling requirements, the chilled water valve shall modulate open to maintain D.A.T. If outdoor air temperature is 50 degrees or lower the chilled water valve shall remain closed:
- d. When the discharge air temperature drops below setpoint, the preheat coil control valve shall first modulate the 1/3 control valve open to maintain setpoint. If unable to maintain setpoint, the 1/3 control valve

shall modulate closed as the 2/3 control valve modulates open as required to maintain setpoint. If the 2/3 valve is 100% open and unable to maintain setpoint, the 1/3 valve shall then modulate open. The control system shall prevent the preheat coil and chilled water coil valves from simultaneous operation.

5. Humidification:

- a. The steam humidifier shall be modulated to maintain the return air relative humidity (30% R.H. adj.) As the humidity of the air increases the humidifier shall modulate down. The reverse shall occur when the humidity of the air decreases. A high limit humidistat shall limit the signal to the humidifier if the humidity of the supply air exceeds 90% R.H. (adj.). The humidifier shall remain off whenever the chilled water valve is opened. Upon a loss in airflow, a panel mounted static pressure switch shall de-energize the humidifier.

6. De-energized/Unoccupied Mode;

- a. In the de-energized mode, the fans shall stop, the outdoor air and exhaust air dampers shall close.
- b. During the unoccupied mode AHU-146 shall reduce its minimum outdoor air CFM 2,000 CFM, to 4,000 CFM.

B. O.R. Rooms

1. OR Rooms shall have positive room differential pressure monitors (DPM's)
2. The DPM display and alarm shall be located outside the OR Door. All alarms shall also alarm the DDC front end. The differential pressure monitors shall come with a door switch to prevent alarms if a door is open.
3. During programmed occupied modes, the VAV supply and return boxes will be at maximum scheduled CFM's. The space thermostat shall modulate the hot water reheat control valve as required to maintain space temperature.
4. During programmed unoccupied modes, the VAV supply boxes will go to 40% of maximum design flow. The corresponding return VAV box will go to a reduced flow to maintain the occupied mode CFM offset.
5. Space mounted humidistats' shall modulate the associated trim humidifiers to maintain space humidity setpoint of 30% RH (ADJ).
6. The O.R.'s will have occupancy sensors provided by E.C. The controls contractor shall use a signal from the occupancy sensor and tie into the BAS. If in unoccupied mode an occupancy sensor is triggered, the VAV terminal shall go into occupied mode and AHU-146 shall go to providing 100% of minimum outdoor airflow. The VAV box and AHU-146 will return to unoccupied mode due to no motion after a programmed time period.

C. Isolation Rooms

1. Isolation rooms shall have negative differential pressure monitors (DPM's.)
2. The DPM display and alarm shall be located outside the isolation room door. All alarms shall also alarm the DDC front end. The differential pressure monitors shall come with a door switch to prevent alarms if a door is open.
3. The VAV supply box will maintain a constant supply CFM. The space thermostat shall modulate the hot water reheat control valve as required to maintain space temperature.

D. Fan Coil Units (FCU-207-212)

1. Provide a manufacturers space temperature sensor where shown on the drawings to control the associated FCU, and associated air cooled condensing units.
2. The fan coil units fan shall run continuously and the DX system shall be cycled on as required.
3. Provide a DDC space temperature sensor in all rooms served by FCUs 207-212 to be used for monitoring and alarming at the DDC front end should any room go above 80° F.

E. Steam Trim Humidifiers:

1. Steam trim humidifiers are provided for the O.R's.
2. Mount high limit duct mounted humidistat to prevent the duct humidity from exceeding 90% RH and airflow switch to prevent humidifier from operating with lack of airflow. Humidistat and airflow switched by humidifier manufacturer.
3. Provide a wall mounted humidistat to maintain space humidity setpoint of 30% RH (ADJ).

F. VAV Box with Hot Water Reheat:

1. As the space temperature rises above the space cooling setpoint, the VAV box damper shall modulate open from the minimum CFM value up to the maximum CFM value to provide space cooling.
2. If the box is at it's maximum CFM position and the space temperature remains above the cooling setpoint, a cooling request shall be sent out to the AHU unit controller. The cooling request shall signal the AHU to provide additional cooling.
3. On a drop in space temperature below the space heating setpoint, the VAV box damper shall modulate closed to allow the minimum CFM value. On a continued drop in space temperature, the reheat coil shall modulate open.

4. For spaces where thermostat also controls perimeter heat, the perimeter heat control valve shall modulate open in unison with VAV box reheat control valve.
- G. Perimeter Radiant Panel and Radiation Control:
1. Where shown on the drawings, the radiant panels and the perimeter radiation shall have independent thermostats controlling the radiant panels, in conjunction with the perimeter radiation.
 2. During the occupied mode the valves shall open and close to maintain space temperature setpoints.
 3. Whenever the outdoor air temperature is above 60°F, the perimeter heat valves shall be closed.
- H. Toilet Exhaust Fans: (EXH- 067)
1. Toilet exhaust fans shall be provided with an automatic damper which shall be interlocked with the fan to "open/close" when the fan is "on/off."
 2. The toilet exhaust fan is intended to run 24/7.
- I. General Exhaust Fans: (EXH-065)
1. General exhaust fans shall be provided with an automatic damper on the suction side of the fan, which shall be interlocked with the fan to "open/closed" when the fan is "on/off."
 2. The general exhaust fan is intended to run 24/7.
- J. Isolation Exhaust Fans (EXH- 066)
1. Isolation exhaust fans shall be provided with an automatic damper on the suction side of the fan, which shall be interlocked with the fan to "open/closed" when the fan is "on/off."
 2. The isolation exhaust fan is intended to run 24/7.
- K. Mechanical Room Exhaust: (EXH-068-070)
1. Provide a space mounted DDC temperature sensor for EXH-068 to 070.
 2. When the space temperature rises above 80 degrees (ADJ) the associated outdoor air intake damper shall open and the exhaust fan shall be energized
 3. When the space temperature drops below 80 degrees the outdoor air intake damper shall close and the exhaust fan shall be de-energized.
- L. Snow Melt System:

1. Snow melt manufacturer's control system with snow/ice melt sensors shall be provided to start/stop snow melt system and to control snow melt supply water temperature setpoints.
2. ATC contractor to coordinate with snow melt manufacturer's control package and wire to all control devices as required.
3. On a call for heat from snow control melt system, the snow melt pump shall start and run. Steam to hot water heat exchanger steam control valve shall modulate as required to maintain snow melt supply water temperature setpoint.
4. Upon a signal to de-energize the snow melt system, the pump shall stop and steam heat exchanger steam control valve shall close.
5. An automatic glycol charging system shall be provided for the snow melt system. Refer to glycol charging detail for alarms for BAS.

M. Unit Heater Control:

1. Unit heaters shall be provided with wall mounted line voltage thermostats. On a drop in space temperature the unit heater fan shall energize and it's hot water valve shall modulate open to maintain space temperature setpoint.

N. Material lift Hoistways:

1. Provide a T-Stat in the Material lift hoistway to open hoistway vent ACD above 85 °F. The hoistway ACD shall also open upon signal from the fire alarm system.

O. Remote Smoke Dampers:

1. A duct smoke detector (provided by E.C installed by HVAC, wired to FACP by E.C and wired to control smoke damper by ATC) upon activation shall close the associated smoke damper upon the presence of combustibles.

1.7 POINTS LIST

A. Note: For point software association, see sequence of operation. All points shall be able to integrate to all trends, totalizers, etc., as applicable. Additional points not specifically called for herein, by required to perform the sequence as specified, shall be provided at no additional cost to the owner.

2. B. The ATC contactor shall carry an allowance for installing, wiring and software programming for 10 additional monitoring and control points of each type (AI, AO, DI, DO) for owners use (i.e. 40 points). These 40 points are over and above points required that are not specifically listed below or required per sequence of operations.

System Point	Point				Alarms			Comments
	A	A	D	D	Hi	Low	Off	

	I	O	I	O			Normal	
Air Handling Units								
Start/Stop Supply Fan				X				
Start/ Stop Return Fan				X				
Supply Fan Status	X				X	X		Via Amp Sensor and Delta P Sensor
Supply Air Flow Volume	X							Via Fan AFMS's
Return Fan Status	X				X	X		Via Amp Sensor and Delta Sensor
Supply smoke Dampers			X	X				Open/Close With End Switch
Return Smoke Dampers			X	X				Open/Close With End Switch
Minimum Outside Air Damper				X				
Economizer Outdoor Air Damper		X						Provide Position Feedback
Relief Air Damper		X						Provide Position Feedback
Return Air Damper		X						Provide Position Feedback
Minimum Outdoor Air Flow Volume	X							Via Air Flow Station At Min Outdoor Air Intake
Return Air Flow Volume	X							Via Fan AFMS's
Return Smoke Detectors			X				X	
Supply Smoke Detector			X				X	
Return Air Temperature	X							
Return Air Humidity	X							Provide Enthalpy Calculations
Mixed Air Temperature	X							
Outdoor Air Temperature (Global PT)	X							
Outdoor Air Humidity (Global PT)	X							Provide Enthalpy Calculations
Heating Coil Leaving Air Temperature	X							
Cooling Coil Freezestat			X				X	
Discharge Air Temperature	X				X	X		
Discharge Air Humidity	X				X			

Humidifier Air Flow Switch			X				X	
Humidifier Start/Stop				X				
Supply Fan VFD Modulation		X					X	Provide VFD Trouble Alarm And All VFD Points Specified
Return Fan VFD Modulation		X					X	Provide VFD Trouble Alarm And All VFD Points Specified
Supply And Return Fans High And Low Static Safety			X		X	X		Via Delta P Switch
Prefilter Dirty Alarm			X		X			Via Filter Delta P
Final Filter Dirty Alarm			X		X			Via Filter Delta P
Discharge Filter Dirty Alarm			X		X			Via Filter Delta P
Preheat Valve		X						Provide Position Feedback
Cooling Valve		X						Provide Feedback
Humidifier Valve		X						Provide position feedback
Supply Duct Static Pressure	X	X						
Return Duct Static Pressure	X	X						RF-146 only
Supply cross tie damper			X	X				AHU-146 and 147 only
Return cross tie damper			X	X				RF-146 and 147 only

System Point	Point				Alarm			Comments
	AI	AO	DI	DO	Hi	Low	Off Normal	
Air Terminal Boxes								
Space Temperature	X				X	X		
Airflow Volume	X							
Modulate Air Terminal Valve		X						
Modulate Reheat Valve		X						

System Points	Points				Alarm			Comments
	AI	AO	DI	DO	Hi	Low	Off Normal	
Radiant Panels/ Baseboard Raditions								
Space Temperature	X					X		
Modulate Hot Water Valve		X						

System Points	Points				Alarm			Comments
	AI	AO	DI	DO	Hi	Low	Off Normal	
Exhaust Fans								
Start/Stop and Status	X		X	X			X	Via Amperage Sensor And DP Sensor
Low Static Safety			X			X		Via Delta P Switch
Fan Isolation Dampers				X				

System Points	Points				Alarm			Comments
	AI	AO	DI	DO	Hi	Low	Off Normal	
Snow Melt System								
Hot Water Supply Temperature	X							
Snow Melt Glycol Tank Low Level			X					
Snow Melt Glycol low pressure			X					
Snow Melt Start/Stop					X		X	From Snow Melt Controller
Hot Water Return Temperature	X							
Snow Melt Pump Start/Stop And Status	X				X		X	Status Via Differential Pressure Across Pump

System Point	Point				Alarm			Comments
	AI	AO	DI	DO	Hi	Low	Off Normal	
Trim Humidifiers								
Space Humidity	X							
Trouble Alarm			X				X	
Space Humidity reset		X						

System Point	Point				Alarm			Comments
	AI	AO	DI	DO	Hi	Low	Off Normal	
Split DX Fan Coil Units								
Trouble Alarm			X				X	
Space temp	X							

System Point	Point				Alarm			Comments
	AI	AO	DI	DO	Hi	Low	Off Normal	
Material lift Hoistway								
Space Temp	X							
Automatic damper				X				
Fire Alarm			X					

System Points	Points				Alarm			Comments
	AI	AO	DI	DO	Hi	Low	Off Normal	
Plumbing/Fire Protection Equipment (Refer to Plumbing Specifications For All Additional Requirements)								
Medical Vacuum Pump System			X				X	From Panel Dry Contact
Master Medical Gas Alarm Panel	X						X	Trouble Alarm From Panel

System Points	Points				Alarm			Comments
	AI	AO	DI	DO	Hi	Low	Off Normal	
Fire Alarm System Signals To FAS								
FAS General Alarm		X					X	

System Points	Points				Alarm			Comments
	AI	AO	DI	DO	Hi	Low	Off Normal	
Miscellaneous Points								
Condense Pump Trouble Alarm			X					

PART 2 - PRODUCTS

(NOT APPLICABLE)

PART 3 - EXECUTION

(NOT APPLICABLE)

END OF SECTION

SEQUENCE OF OPERATIONS