

SECTION 23 09 93 - SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.1 SUMMARY

- A. This section describes the sequence of operations for HVAC control systems specified elsewhere in these specifications.
- B. Related Work: The requirements of Section 23 05 00, Common HVAC Materials and Methods, also apply to this section.
- C. To be completed under contract directly for Owner.

PART 2 - SEQUENCE OF OPERATION

2.1 LEVEL OF DETAIL

- A. Match current level of detail.
- B. Sequences for systems other than chiller plant to remain the same unless noted otherwise.

2.2 SEQUENCE OF OPERATION - CHILLER

- A. Building Cooling Demand Calculation: Building cooling demand shall be calculated by taking the sum of all the cooling control valve positions, weighted by the scheduled valve flow rate and averaged by the total combined flow rate for all of the valves.

$$\text{Cooling Demand}_{\text{Building}} = \frac{\sum_{i=1}^{\text{total \# of valves}} \left(\text{Cooling Valve Position}_i \times \frac{1}{100} \times \text{Scheduled Flow Rate}_i \right)}{\text{Total Flow Rate}}$$

- B. Chiller Supply Water Setpoint Reset: Supply water temperature setpoint shall be linearly reset based on the building cooling demand as described in the following schedule:

Chiller Supply Water Reset Schedule	
Building Cooling Demand (%)	Supply Water Set Point (F)
0	55
>75	45

**All reset values shall be adjustable through the operators workstation.

C. Chiller Operation

1. The chiller shall be controlled by the master control panel (provided by the chiller manufacturer) based on the leaving chill water temperature set-point.
2. One of the compressors in each chiller module shall be controlled by VFD. Due to compressor oil sludge problems [chillers with compressors located below the evaporator] the compressor speed shall not be reduced below 58%.
3. The chiller shall not operate when no flow is detected at the flow switches.
4. A minimum pressure difference across the thermal expansion valve must be maintained in equivalence to 30 deg. F difference between saturated liquid temperature in the condenser and the saturated vapor temperature in the evaporator.
5. The allowable water flow through the evaporator shall be based on a delta T of 5 deg. F. minimum and 20 deg. F maximum (2.4 gpm/ton nominal).
6. The allowable water flow through the condenser shall be based on a delta T of 5 deg. F. minimum and 30 deg. F maximum (3.0 gpm/ton nominal).
7. The allowable leaving condenser water temperature shall be 60 deg. F minimum and 95 deg. F maximum.
8. The allowable leaving chill water temperature shall be 40 deg. F minimum, and 62 deg. F maximum.
9. The condensing and the chill water headers' bypass valves shall operate based on the condensing/chiller water header loops' differential pressure sensors to prevent dead-heading the pumps when flows are greater than the chiller flows.

D. Heat Exchanger Operation

1. When changing from the water-side economizer to chiller cooling operation, the condensing water supply may be below the minimum chiller set-point. When such condition exists, the condensing water must be re-circulated *through the economizer heat exchanger* and the condensing supply minimum temperature control valve, up to the point where the chiller allowable minimum temperature is reached.
2. The heat exchanger shall function when condensing water supply temperature is at set-point or the water supply temperature shall be below the chiller minimum allowed condensing water temperature.
3. To operate the water side economizer, the condensing water and the chill water 3-way bypass valves shall be controlled to divert the chill water and the condensing water flows from the chiller loop to the heat-exchanger loop.
4. Condensing Water Loop Economizer: This system is equipped the ability to direct condensing water from the tower loop to the building chilled water piping system. This by-passes the chiller and provided a level of cooling at the air handler chilled water valves.
 - a. When the economizer mode is activated:
 - 1) Disable chiller operation and wait for status off to be confirmed.
 - 2) Open the normally closed (NC) valves (typical of 2) that allow condensing water to flow around the chiller. Confirm valves are open.

- 3) Close the normally open (NO) valves (typical of 4) that allow chilled water and condensing water to flow to and from the chiller.
 - 4) To revert back to chiller operation; proceed through sequence in reverse.
 - b. Allow economizer mode when any of the below conditions are true:
 - 1) The outside air temperature is below 53 deg. F (adj). and no event is scheduled for the next 12 hrs (adj).
- E. Cooling Tower Operation
 1. Tower Operation: Integrate via BACnet MS/TP connection. Provide 4-20mA variable signal with range from 45 deg. F. to 200 deg. F. Operate to maintain 85 deg. F. (adj.) condensing water temperature set-point during chiller operation. During water side economizer operation operate for 50 deg. F. condensing water set-point. Provide auxiliary connection to VFD for remote operation of tower drive directly. Provide toggle on system graphic with highlighted indication that tower controller is by-passed when controlling drive directly. Direct VFD modulating signal shall be 0-10 volt. Enable / disable on signal from chiller. Pan heater and condensing water heat trace operation from BAS based on OSA temperature.
 2. When condensing water temperature drops below the minimum set-point the cooling tower fans' speed shall be reduced or the fans shall be turned off. When condensing water temperature is still below the minimum set-point, the minimum temperature control valve shall modulate to re-circulate condensing water and/or bypass the cooling tower.
 3. When the outdoor temperature is above freezing, the minimum flow through the tower shall be 100 gpm/nozzle or more.
 4. When the outdoor temperatures are at or below freezing, the minimum flow through the tower shall be 200 gpm/nozzle or more.
 5. The leaving water temperature shall be no less than 45 deg. F at full fan speed. Fans shall be operated on a reduced speed or be off periodically for ice removal in the water collection system. The leaving water temperature shall be 43 deg. F or greater when the fans run at reduced speeds.
 6. The perimeter basing heater shall be off during active cooling tower water flow.
 7. The basin temperature sensor provided by the tower manufacturer, shall be field installed. The controller is factory preset at 45 deg.F.
- F. Pumping System Operation
 1. Condenser Pump Control: When pump is enabled, VFD shall modulate from minimum speed (25% adjustable) to maintain system static pressure across the condensing side of the chiller. Enable lag pump if lead is at full speed for more than 5 (adj.) minutes. Disable lag if both pumps have operated for 5 minutes at less than half speed. When pumps are disabled, VFD speed is set to 0%. On system start-up, system static pressure is the average of the min. & max. range.

2. Chilled Water Pump Enable/Disable (CWP-1, CWP-2): Lead pump operation will be enabled if any two (2) (adjustable) valves are open more than 20% (adjustable). Operate to maintain system static pressure at the building DP sensor and the minimum pressure across the chiller measured by the DP sensor near the chiller. Enable lag pump if lead is at full speed for more than 5 (adj.) minutes. Disable lag if both pumps have operated for 5 minutes at less than half speed. Disable chilled water pump five (5) minutes after chiller operation has been disabled. On system start-up, system static pressure is the average of the min. & max. range.
 3. Chiller Enable/Disable: Chiller shall be enabled when lead pump run status is proven. Disable chiller when all valves are closed more than 5% (adjustable) or the outside air temperature is below 55°F (adjustable). Chiller will maintain remote supply water setpoint internally.
 4. Pump Lead/Lag (CDP-1/CDP-2, CWP-1/CWP-2): Operate pumps based on lead/lag. On failure of lead pump, operate lag pump and send alarm. Switch lead operation every one hundred (100) (adjustable) hours of run time. Lead selection shall also be selectable from the operator's workstation, resetting the current run-hours-until-switch when used. When switching from lead pump to lag pump allow both pumps to operate a minimum of fifteen (15) seconds before disabling the lead pump.
- G. Other System Sequences
1. System Lockout: If any system critical pump fails three (3) times during an operational period the system shall lockout and an alarm sent to the workstation. If the LWT exceeds 110°F (adjustable) during an operational period system shall lockout and an alarm sent to the workstation. Lockout(s) is resettable from the operator's workstation.
 2. Refrigerant Monitoring Alarm: If the refrigerant monitoring alarm is active, send alarm to the operator workstation and disable all chilled and condensing water equipment from operation. Minimum wait time before restarting equipment is five (5) minutes regardless of alarm status. Disable boiler plant immediately regardless of minimum run time sequences.

2.3 EXHAUST FANS

- A. Mechanical Room Exhaust Fan (EF-7): Operate when space temperature exceeds 80° F (adjustable). Scheduling not associated with this unit.
1. Automatic Damper Control (EF-7/AUD-7): Open damper when associated exhaust fan is in operation.

END OF SECTION