SECTION 15985 - SEQUENCE OF OPERATION

1.01 SUBMITTALS
   A. Written sequence of operation to be submitted with shop drawing submittal of Section 15970.

PART 2 - PRODUCTS

2.01 GENERAL
   A. The HVAC with controls shall be installed and programmed to perform as described in this section, and as applicable to the specific project.

PART 3 - EXECUTION

3.01 SEQUENCE OF OPERATION
   A. Start/Stop, (S/S) AHU
      1. With the H-O-A switch on the starter panel, in the "H" position, the system shall be energized and the system safety devices shall protect the circuit.
      2. With the H-O-A switch on the starter panel in the "H" position, the unit will start.
      3. With the H-O-A switch in the "A" position, the unit will operate in response to DDC control and system safety circuits.
      4. Programs
         a. Schedule
      5. Control Points
         a. Start/Stop
         b. Status

   B. Optimum Start (OST), AHU
      1. Scheduled start time, controlled by the DDC controller, can be altered by controllers optimum start program calculation.
      2. The result of the calculation is to compute the equipment start time so that the space temperature can be moved from its unoccupied mode setting, to the occupied mode setting for the space controlled, early enough to meet the scheduled start time for the space.
      3. Programs
         a. Schedule
         b. Start/Stop Program
         c. Optimum Start/Stop Program
         d. Outside/Return/Relief Dampers
         e. DDC - Historical temperature rate of change (from selected sensor)
      4. Control Points
         a. Outside Air Temp.
         b. Outside Air Humidity
         c. Space Temp.
         d. Start/Stop, AHU Fan

   C. Optimum Stop (OSP), AHU
      1. Scheduled stop time, controlled by the DDC controller, can be altered by controllers optimum start/stop program.
2. The result of the calculation is to compute the equipment stop time, so that the space temperature is allowed to drift from its occupied mode setting for the space controlled, to the upper or lower temperature limit by the scheduled stop time.

3. Programs
   a. Schedule
   b. Start/stop program
   c. Optimum start/stop program
   d. DDC - Historical temperature rate of change

4. Control Points
   a. Outside Air Temp  X
   b. Space Temp    X
   c. Start/Stop, AHU    X

D. Unoccupied Mode (UM), AHU and Terminal Units

1. Room occupancy sensor, along with the “Time of Day” program will cause the AHU's and terminal units to go to unoccupied mode settings when called for by the schedule program.
2. Space temperature settings to be reset to 55°F winter and 85°F summer.
3. Outside air damper to close.
4. During heating season, the DDC shall use space temperature sensors to cycle the AHU to prevent the space temperature from falling below the minimum setpoint. The outside air damper shall remain closed.
5. Programs
   a. Time of Day Schedule
   b. Optimum Start/Stop
   c. Day/Night, Occupant Override

6. Control Points
   a. Unoccupied space temp.  X
   b. Start/Stop, AHU/Pneu. controls  X
   c. Outside air damper closed  X
   d. Occupancy/Vacancy Switch  X

E. Occupied Mode (OM), AHU//Terminal Units//

1. Room occupancy sensor and terminal unit controller, along with “Time of Day” program for occupied rooms will cause the AHU to start and run continuously and controls to be energized.
2. AHU controls will be energized and switched from unoccupied temperature setting to an occupied setting (72°F minimum and 78°F maximum).
3. Outside air damper to go to position for required outside air volume, for occupied spaces only.
4. Programs
   a. Time of Day Schedule
   b. Optimum Start/Stop Schedule
   c. Day/Night/Occupant Override Switch

5. Control Points
   a. Occupied space temp.  X
   b. Start/Stop, AHU Pneu. Controls  X
   c. Outside air damper to minimum position  X
   d. Occupancy/Vacancy Switch  X

F. Enthalpy Economizer Control (EEC), AHU
Note: Designer/UC to choose between (EEC) and (TEC).

1. Each DDC controller to perform an enthalpy calculation to determine when it is more energy efficient to use outside air for cooling.

2. Based on these data and the enthalpy calculation, DDC controller will modulate outside air, return air and exhaust air dampers to achieve mixed air temperature setpoint.

3. When outside air (OA) enthalpy is greater than return air enthalpy, the OA damper will return to minimum position.

4. Programs
   a. DDC - enthalpy computation.

5. Control Points

   a. Outside air temp. X
   b. Outside air humidity X
   c. Return air temp. X
   d. Return air humidity X
   e. Mixed air temp. X
   f. Outside air damper X
   g. Return air damper X
   h. Exhaust air damper X

G. Temperature Economizer Control (TEC), AHU

Note: Designer to choose between (EEC) and (TEC).

1. DDC controller to modulate outside air, return air and exhaust air dampers to achieve mixed air temperature setpoint.

2. When the outside air temperature is greater than the return air temperature, the outside air damper will return to minimum position.

3. When the mixed air temperature (MAT) falls below setpoint [55°F] the outside damper shall go to minimum position.

4. If cooling is required, but the return air temperature is lower than the OA temperature, the OA dampers will go to their minimum position.

5. If the return air temperature is below an operator definable limit, then a warm-up cycle shall be initiated forcing the outside air dampers to their closed position. (See WARM-UP CYCLE.) When return air temperature increases above the limit, plus a definable differential, then the warm-up cycle shall be terminated.

6. Programs.
   a. DDC - Setpoint computation
   b. DDC - Setpoint control

7. Control Points

   a. Outside air temp. X
   b. Return air temp. X
   c. Mixed air temp. X
   d. Outside air damper X
   e. Return air damper X
   f. Exhaust air damper X

H. Warm-up Cycle Control (WCC)

1. When schedule calls for occupied mode startup, and the return air temp is 5°F or more below setpoint (70°F), a “warm-up” cycle shall initiate.

2. Outside air damper will close.

3. Heating control valve will open.
4. Terminal box reheat to full heat.
5. VAV terminal box damper to full open.
6. When return air temperature increases above the setpoint, the warm-up cycle shall terminate.
7. Programs
   a. Schedule
   b. DDC - Setpoint control
   c. Occupied mode
8. Control Points
   a. Return air temp.  
   b. Outside air damper
   c. Terminal box damper
   d. Terminal box reheat coil

I. Return Air or Supply Air Smoke Detection, (SD) AHU
   1. Air duct smoke detector, upon sensing smoke, shall stop the fan(s) and de-energize controls
      through a direct circuit normally closed (NC) interlock contacts.
   2. A set of normally open (NO) contacts will close, to signal the fire alarm system.
   3. A second set of NO contacts shall close and signal the Central Operating Terminal.
   4. Programs
      a. Alarms and Messages
   5. Control Points
      a. Smoke Detector
      b. Alarm signal and report

J. Filter Maintenance (FM), AHU
   1. Differential pressure switch with sensors on upstream and downstream side of filter will signal
      DDC controller when the differential pressure is equal to or greater than the setpoint.
   2. DDC controller will initiate an alarm signal indicating a clogged filter and requirement for
      maintenance.
   3. Programs
      a. DDC - Alarms and messages
   4. Control Points
      a. Differential Pressure Switch

K. Supply Air Temperature (SAT) Control, AHU.
   1. SAT setpoint established by DDC controller (usually 55°F).
   or
   1. SAT reset based on requirements of individual terminal box with the most cooling requirement
      (i.e. zone temperature with most deviation to high side of setpoint).
   or
   1. SAT is reset down until all zone temperatures are satisfied. Conversely SAT is reset up as zone
      setpoints all deviate to the low side.
   2. DDC controller shall reset the mixed air temp (MAT) control loop setpoint (Economizer
      control), and the heating coil air temp control loop setpoint, to correlate to supply air temp
      (SAT) setpoint.
   3. SAT shall modulate the cooling coil control loop to maintain SAT setpoint.
   4. MAT control loop shall modulate the economizer dampers to maintain MAT setpoint.
   5. Heating coil control loop leaving air temp shall modulate the heating coil valve to maintain
      HC/LAT setpoint.
Face and bypass damper control (F & B), AHU

6. DDC controller shall modulate face and bypass air dampers and hot water coil valve in concert, at outdoor temperatures above 40°F to achieve coil leaving air temperature setpoint; and modulate the bypass damper only (coil valve at 100% open) when outdoor air temperatures are less than 40°F.

7. Programs
   a. DDC-PID Loop Control

8. Control Points.  
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L. Preheat Control (PHC)

1. DDC controller will modulate the preheat coil control valve to maintain a preset coil//air discharge temperature [or mixed air temperature as shown on drawings].

2. Programs
   a. DDC - PID setpoint control

3. Control Points  
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 M. Variable Speed Control (VSC), AHU.

1. DDC controller will modulate fan speed with a 4-20 MA signal to variable frequency drive based on duct pressure sensor.

2. As duct pressure decreases, fan speed will increase. As duct pressure increases, fan speed will decrease.

3. Programs
   a. DDC - PID Loop Control, maximum rate of speed change.

4. Control Points  
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 N. Variable Inlet Vane Control (VIV), AHU

1. The DDC controller will modulate fan inlet vanes, based on duct pressure sensor.

2. As duct pressure decreases, variable inlet vanes open. As duct pressure increases, the variable inlet vanes close.

3. Programs
   a. DDC - PID Loop Control, maximum rate of damper movement.

4. Control Points  
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 O. Return Fan Tracking Control (RFT), AHU

1. DDC controller shall modulate the return fan \([speed][\text{variable inlet vane position}]\) to maintain return air velocity pressure setpoint.
2. Return air velocity setpoint equals actual supply air velocity pressure, minus a differential equal to minimum outside air flow requirements.
3. Programs
   a. DDC - PID, Setpoint Computation and Control
4. Control Points
   a. Supply air velocity pressure (flow) \(X\)
   b. Return air velocity pressure (flow) \(X\)
   c. Return fan speed \([or VIV] X\)

P. Humidity Control (HC), AHU

1. Interlock with supply fan to close humidification control valve when supply fan is off.
2. DDC shall modulate humidity control valve to increase humidity in response to return air relative humidity.
   Substitute "Space" for "return air" where appropriate.
4. Return air relative humidity setpoint shall be reset based on outside air temperature reset schedule.
   Note: Supply air High Limit shall be a pneumatic sensor, with a branch line that bleeds air from the humidifier signal upon reaching the High Limit.
5. Programs
   a. DDC - PID, Setpoint Control
   b. Control Point Reset
6. Control Points
   a. Return or exhaust air humidity \(X\)
   b. Humidifier Control Valve \(X\)
   c. Outside Air Temperature \(X\)

Reheat coil sizing must take into consideration that cooling coil may precool to control humidity.

Q. Terminal VAV Box, Cooling Only Control

1. DDC shall modulate variable volume damper in response to space temperature sensor.
2. When space temperature exceeds the setpoint, the variable volume damper will modulate open. As the temperature falls the damper shall modulate to minimum position.
3. A "High/Low" position limit may be implemented to limit the minimum and maximum airflow.
   (Note: VAV terminal box shall have built-in flow compensation control.)
4. Programs
   a. DDC - PID, Setpoint Control
5. Control Points
   a. Space temperature \(X\)
   b. VAV damper \(X\)
   c. Day/Night Switch \(X\)
   d. Occupant Override \(X\)

R. Terminal VAV Box, Hydronic Reheat Coil, Control.
1. DDC shall modulate variable volume damper and reheat coil valve in sequence to achieve space temperature setpoint.

2. When space temperature exceeds the cooling setpoint, the variable air volume (VAV) damper will modulate open. As the temperature falls, VAV damper modulates to minimum position. Minimum position will be based on the greater requirements of: Heating load, supply air temperature or ventilation air requirements.

3. After damper reaches minimum position, the space temperature shall drift in a dead-band until reaching the heating control setpoint. As temperature continues to fall below setpoint, reheat coil valve shall modulate open.

4. There are two modes of operation for setpoints, one for "occupied" mode (heating = 72°F, cooling = 74°F, adjustable) and one for "unoccupied" mode (heating = 55°F, cooling = 82°F, Adjustable). Refer to occupied/unoccupied mode control.

5. Programs
   a. DDC - PID, Setpoint Control
   b. Day/Night
   c. Occupancy Override

6. Control Points
   a. Space Temperature
   b. VAV Damper
   c. Reheat Control Valve
   d. Day/Night Switch
   e. Occupancy Override

S. Terminal VAV Box, Electric Reheat Coil, Control.

1. DDC will modulate variable volume damper and reheat coil heating stages in sequence to achieve space temperature setpoint.

2. When space temperature exceeds the cooling setpoint, the variable air volume (VAV) damper will modulate open. As the temperature falls, VAV damper modulates to minimum position. Minimum position will be based on the greater requirements of: Heating load, supply air temperature or ventilation air requirements.

3. After damper reaches minimum position, space temperature shall drift in a deadband until reaching the heating control setpoint. As temperature continues to fall below setpoint, electric coil stages of heat will be energized.

4. There are two modes of operation for setpoints, one for "occupied" mode (heating = 72°F, cooling = 74°F, adjustable) and one for "unoccupied" mode (heating = 55°F, cooling = 82°F, Adjustable). Refer to occupied/unoccupied mode control.

5. Programs
   a. DDC - PID, Setpoint Control
   b. Alarms and Messages:
      - Zone temp., high and low
      - Discharge air temp., high and low
   c. Day/Night Switch-Over
   d. Occupancy Override Switch

6. Control Points
   a. Space temperature
   b. VAV damper
   c. Electric coil
      Stage I
      Stage II

   If required.

Use series FP/VAV boxes to achieve constant air flow to the space.
d. Day/Night Switch X  
e. Occupancy Override X

T. Series Fan Powered Terminal Box, VAV, Reheat (SFP/VAV)

1. During occupied mode, fan runs continuously.  
2. The DDC will modulate the VAV cooling/return air damper and reheat coil valve in sequence to achieve space temperature setpoint.  
3. When space temperature exceeds the cooling setpoint, the variable air volume (VAV) damper will modulate open. As the temperature falls VAV damper modulates to minimum position.  
   Minimum position will be based on the greater requirement of: Heating load, supply air temperature or ventilation air requirements.  
4. After damper reaches minimum position, the space temperature shall drift in a dead-band until reaching the heating control setpoint. As temperature continues to fall below setpoint, reheat coil valve shall modulate open.  
5. There are two modes of operation for setpoints, one for "occupied" mode (heating = 72°F, cooling = 74°F, adjustable) and one for "unoccupied" mode (heating = 55°F, cooling = 82°F, Adjustable). Refer to occupied/unoccupied mode control.  
6. During unoccupied mode, fan will only operate when space temperature exceeds setpoint (either high or low). The damper will remain closed.

7. Programs  
   a. DDC - PID, Setpoint Control  
   b. Alarms and Messages:  
      - Zone temp., high and low  
      - Discharge air temp., high and low  
   c. Day/Night Switch - Over  
   d. Occupancy Override Switch

8. Control Points
   a. Space temperature X  
   b. VAV damper X  
   c. Reheat control valve X  
   d. Fan X  
   e. Day/Night Switch X  
   f. Occupancy Override X

Use parallel PFP/VAV boxes to deliver heat to space.

U. Parallel Fan Powered Terminal Box, VAV, Reheat (PFP/VAV)

1. During occupied mode, fan will operate when VAV damper closes to 30% of open or less.  
2. The DDC will modulate the VAV cooling damper and reheat coil valve in sequence to achieve space temperature setpoint.  
3. When space temperature exceeds the cooling setpoint, the variable air volume (VAV) damper will modulate open. As the temperature falls VAV damper modulates to minimum position.  
   Minimum position will be based on the greater requirement of: Heating load, supply air temperature or ventilation air requirements.  
4. After damper reaches minimum position, the space temperature shall drift in a dead-band until reaching the heating control setpoint. As temperature continues to fall below setpoint, reheat coil valve shall modulate open.  
5. There are two modes of operation for setpoints, one for "occupied" mode (heating = 72°F, cooling = 74°F, adjustable) and one for "unoccupied" mode (heating = 55°F, cooling = 82°F, Adjustable). Refer to occupied/unoccupied mode control.  
6. During unoccupied mode, fan will only operate when space temperature exceeds setpoint (either high or low). The VAV damper remains closed.
7. Programs
   a. DDC - PID, Setpoint Control
   b. Alarms and Messages
      - Zone temp., high and low
      - Discharge air temp., high and low.

8. Control Points

   a. Space temperature
   b. VAV damper
   c. Reheat coil valve
   d. Fan

V. Water Source Heat Pump

1. During occupied mode the fan runs continuously.
2. DDC shall verify water loop is flowing and water temperature is within the allowable limits
   (low temp. = 60°F, high temp. = 90°F) and permit heat pump compressor to operate.
3. Space temperature will cycle the reversing valve to cooling when cooling temp. limit is
   exceeded and to heating when heating temp. limit is exceeded.
4. Programs
   a. DDC - Setpoint Control

5. Control Points

   a. Space temperature
   b. Heat pump

Following paragraphs (W,X,Y, and Z) pertain to a multiple pump, constant volume distribution system
with constant volume chiller and condenser pumps.

W. Chilled Water Distribution System

1. DDC shall start one system pump which shall run continuously [or start when any one AHU
   CHW control valve begins to open].
2. System pump flow status is verified by current sensor.
   Or
2. System pump flow status is verified by flow meter setpoint.
3. If system flow is not verified within specified time delay (30 seconds), an alarm shall be
   initiated.
4. If flow is detected and system pump is "off", a separate alarm signal shall be initiated.
5. System pump variable speed drive will modulate to maintain the end of main system
   differential pressure (10-20 psid adjustable).
6. Second system chilled water pump will start if the end of main differential pressure falls below
   setpoint (20 psid). Both pumps will modulate at the same speed to satisfy the differential
   pressure demand. When the system flow falls to set point (50%-60% at max. design) the
   second pump shall shut down.
   (Note: Each pump shall be sized for 100% load.)
7. Cooling load shall be calculated and ton-hours consumed shall be totalized. Calculation based
   on flow rate and temperature differential. (This value is to be used for billing and or system
   evaluation.)
8. Programs
   a. DDC-PID setpoint control and load computation
   b. Alarms and reports
9. Control Points

   a. Supply Water Temperature
b. Supply Water Pressure X
c. Supply/Return Water Differential Pressure X
d. Return Water Temperature X
e. Return Water Pressure X
f. Return Water Flow X
g. Option for Highest Demand AHU CHW Valve Virtual
h. CHW Pump S/S X
I. CHW Pump Flow Status X

X. Condenser Water System Pump.

1. DDC will start the condenser water (CW) pump when the CHW system pump is started.
2. Condenser water pump flow status is verified by motor current sensor.

Or

2. Condenser water pump flow status is verified by flow switch.
3. If system flow is not verified within specified time delay, an alarm shall be initiated.
4. If flow is detected and CW pump is off, a separate alarm signal shall be initiated.
5. Programs
   a. DDC - PID Setpoint Control
6. Control Points
   a. CHW status pump on X
   b. CW pump on X
   c. CW pump flow status X
   d. CT level low X

Y. Chiller System.

1. DDC controller shall start chiller pump when system CHW return temperature rises above setpoint (56°F).
2. Chiller pump flow status shall be verified by motor current sensor.
3. When chiller pump flow is verified, chiller shall start and control supply water temperature.
4. CHW supply temperature set at 45°F.
5. Chiller "ON" status shall be verified within specified time delay, or an alarm signal initiates.
6. Chiller safety circuit shall generate an alarm signal if any safety switch trips.

Centrifugal chiller supply water temperature control.

7. DDC shall modulate chiller compressor inlet vane control to achieve supply temperature setpoint.

Or

Reciprocating chiller supply water temperature control.

8. DDC shall sequence compressor stages, individual compressors, unloaders; to achieve setpoint target. Ramp schedule will limit temperature rate of change.
9. Programs
   a. DDC - PID setpoint control
   b. Alarms and Reports:
      - CHW pump not running
      - CW pump not running
      - Chiller not running
      - Chiller "OFF" by safety circuit.
   c. Chilled water temperature setpoint optimization.
10. Control Points
    a. Highest demand AHU CHW control valve (option) X
    b. Chiller pump on X
c. Chiller pump flow status X
    d. Chiller on X
    e. Chiller status X
    f. Chiller capacity control X
    g. Chiller safeties X

Z. Condenser Water System Control.

1. DDC shall modulate cooling tower (CT) bypass valve and sequentially stage CT fans to achieve condenser water supply temperature setpoint. Condenser water temperature shall float between upper control limit of 85°F and lower control limit of [55°F].

2. Programs
   a. DDC - PID setpoint control
   b. Condenser water temperature setpoint optimization w/low condenser pressure protection limit.

3. Control Points
   a. Condenser water supply temp. X
   b. CT bypass valve. X
   c. CT fans X
   d. Condensor pressure X

Following paragraphs (W,X,Y, and Z), pertain to a chilled water multiple pump, variable volume distribution system with constant volume chiller and condenser pumps.

AA. Chilled Water Distribution System

Edit time delay and pressure differentials as required by design.

1. DDC shall start one system pump when any one AHU CHW control valve begins to open and shall stop last pump on, when last AHU CHW control valve closes.

2. System pump flow status is verified by motor current sensor.

3. If system flow is not verified within specified time delay, an alarm shall be initiated. (seconds)

4. If flow is detected and system pump is "off", a separate alarm signal shall be initiated.

5. System pump variable speed drive will modulate in response to supply and return system pressure. (_____ psid)

6. If one pump cannot maintain the differential pressure, the second system pump will start, and both pumps will modulate at the same speed to satisfy the differential pressure demand. When flow falls to minimum speed setting, one pump shall shut down, and as flow continues to fall, the end of line crossover control valve will modulate open to maintain a minimum flow (_____ psid).

7. The third pump is a standby unit and can be operated in place of either of the other pumps.

8. Primary parameter indication shall be sensed for:
   - Supply Water Temperature
   - Supply Water Pressure
   - Supply/Return Differential Pressure
   - Return Water Temperature
   - Return Water Pressure
   - Return Water Flow
   - Crossover Flow

9. Programs
   a. DDC, setpoint control

10. Control Points
    a. AHU CHW control valve demand X
    b. CHW system pump On/Off X
c. CHW system pump flow status X
d. Supply water temperature X
e. Supply water pressure X
f. Supply/Return Differential Pressure X
g. Return water flow X
h. Return water pressure X
i. Return water temperature X
j. Decoupler flow X
k. CHW pump variable speed drive X

AB. Condenser Water Circulation System

1. DDC will start a condenser water (CWP) pump and open associated chiller condenser valve when the first chiller is started.
2. The second and third CW pumps will start when the second and third chillers start, respectively. Likewise they will shutdown when the chillers are shutdown.
3. Condenser water pump operation status is verified by motor current sensor. 
   Edit time delay as required.
4. If system flow is not verified within specified time delay (___ seconds), an alarm shall be initiated.
5. If flow is detected and CW pump is off, a separate alarm signal shall be initiated.
6. CT bypass valve shall modulate and fans shall sequence to control condensor water setpoint.
7. Programs
   a. DDC - start/stop
8. Control Points
   a. CH start X
   b. CW pump start X
   c. CW condenser flow status X
   d. CT level low X
   e. Condensor Pressure X

AC. Chilled Water Generation System

Edit time delay and CHW flow rate as required by design.

1. DDC controller shall start a chiller pump, open to CH valve and send start signal to CH when system CHW return temperature rises above setpoint (56°F).
2. Chilled water flow status shall be verified by differential pressure across the CH evaporator (setpoint ___ gpm).
3. When chiller evaporator flow is verified, and chiller permissive controls are satisfied, the chiller shall start.
4. Chiller controls shall modulate chiller compressor inlet vane control to achieve leaving temperature setpoint. Ramp schedule will limit temperature rate of change.
5. Chiller "ON" status shall be verified within specified time delay (90 seconds), or an alarm signal initiates.
6. Chiller safeties circuit shall generate an alarm signal if any safety switch trips.
7. Facility Management Programs
   a. DDC - PID.
   b. Setpoint Control
   c. Alarms and Reports:
      - CH pump not running
      - CH evaporate low flow
      - Chiller not running
      - Chiller "OFF" by safety circuit.
8. Control Points

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AD. Condenser Water System Control.

1. Start CW pump (CWP-1 or CWP-2 or CWP-3) and verify flow status by motor current sensor.
2. When CW pump (CWP-1 or CWP-2 or CWP-3) flow is proven, DDC shall modulate cooling tower (CT) bypass valve and sequentially stage CT cell valves and fans to achieve condenser water supply temperature setpoint. Condenser water temperature shall float between upper control limit of 85°F and lower control limit of 55°F.
3. Programs
   a. DDC - PID, setpoint control

4. Control Points

<table>
<thead>
<tr>
<th></th>
<th>AI</th>
<th>AO</th>
<th>BI</th>
<th>BO</th>
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</thead>
<tbody>
<tr>
<td>a. CW CH condenser flow status</td>
<td></td>
<td></td>
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<td>X</td>
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<tr>
<td>b. Condenser water supply temp.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>c. CT bypass valve.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>d. CT fans</td>
<td></td>
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<td>X</td>
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<tr>
<td>e. CW return temperature</td>
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<td></td>
<td>X</td>
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<tr>
<td>f. CT, CW valve</td>
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</tbody>
</table>

Following paragraphs (AA and AB) pertain to a multiple pump, constant volume heating water system.

AE. Heating Water Circulation Pump (HWCP)

1. DDC shall start HW Circulation pump in response to any AHU with a heating demand as determined by HW control valve position signal.

Or

1. DDC controller shall start HW Circulation pump in response to outside air temperature at and below setpoint (60°F).

Or

1. HW circulation pumps shall be started by Operator, through DDC manual command.
2. HW circulation pump flow status shall be verified by motor current sensor.
3. If HW circulation pump flow is not verified within specified time delay, an alarm shall be initiated.
4. If flow is detected and pump is off, a separate alarm shall be initiated.
5. Programs
   a. DDC - PID setpoint control
   b. Alarms and Reports
6. Control Points

<table>
<thead>
<tr>
<th></th>
<th>AI</th>
<th>BO</th>
<th>BI</th>
<th>BO</th>
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</thead>
<tbody>
<tr>
<td>Pump start on heating demand.</td>
<td></td>
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<td></td>
<td>X</td>
</tr>
<tr>
<td>a. AHU heating control valve.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Pump start on outside air temp.

1. a. Outside air temp. |    |    |    | X  |

Pump start by operator.

1. a. Operator command |    |    |    | X  |
b. Pump start
   c. Pump flow status

AF. Heating Hot Water Generation System

1. DDC shall start boiler when HWCP is verified on and a defined time delay.
2. Boiler "ON" status shall be verified within specified time delay, or an alarm signal initiates.
3. Boiler safeties circuit shall generate an alarm signal if any safety switch trips.
4. Boilers - manufacturer supplied control will modulate the burner valve to maintain boiler hot water temperature.
5. DDC shall reset the boiler temperature in response to any hot water control valve signal from valve with the most demand. When any hot water control valve reaches maximum open position, the boiler hot water temperature setpoint will be reset higher. (Maximum temperature = 200°F, minimum temperature = 140°F).

Or

6. DDC shall reset boiler hot water temperature based on an outside air temperature reset schedule (Hot water temperature = 200°F at 0°F outside air temperature, hot water temp. = 140°F at 60°F outside air temperature).

7. Programs
   a. DDC - PID setpoint control
   b. Temperature reset

8. Control Points

   

   AI   AO   BI   BO

   a. Hot water circulating pump status
   b. Boiler Status
   c. Boiler Safeties Circuit
   d. Boiler Temp. Reset
   e. System Hot Water Control
   f. Outside air temp.

Boiler temp. reset based on load.

   e. System Hot Water Control

Boiler temp. reset based on outside air temp.

   e. Outside air temp.

Following paragraphs (AA and AB) pertain to a heating water, pump, variable volume distribution system with constant volume boiler pumps.

AG. Heating Water Distribution System

1. DDC shall start first HW system pump in response to any AHU with a heating demand as determined by HW control valve position signal.
2. HW system pump flow status shall be verified by motor current sensor.
3. If HW system pump flow is not verified within specified time delay, an alarm shall be initiated.
4. If flow is detected and pump is off, a separate alarm shall be initiated.
5. HW system pump variable speed drive will modulate in response to system supply and return pressure differential (_psid).
6. If one pump cannot maintain the differential pressure setpoint, the second system pump shall start, and both pumps will modulate at the same speed to satisfy the differential pressure demand.
7. When flow falls to minimum speed setting, one pump shall shutdown. When all AHU control valves are satisfied, the last system pump shall shut down.
8. Programs
   a. DDC - setpoint control
   b. Alarms and Reports

9. Control Points

   

   AI   AO   BI   BO

   a. AHU heating control valve.
b. Pump start X

c. Pump status X

d. System supply/return dp X

e. Crossover bypass valve X

f. Pump variable speed drive X

AH. Heating Hot Water Generation System

1. DDC shall start boiler, boiler HWP, open combustion air damper (start ventilation fan) and open boiler control valve when flow is sensed in the direction of A to B in the system crossover line.

2. The flow through the crossover line will immediately reverse to a "B" to "A" direction. Flow will gradually diminish as the system flow increases until it again reverses, to flow in the "A" to "B" direction. This process will repeat as the load increases, starting each of the other boilers in succession.

NOTE: The small boiler shall be the base boiler during spring, summer, and fall; and shall be the last in sequence during the winter (December, January, February).

3. Boiler HWP flow shall be verified by motor current sensor, within specific time delay or an alarm signal will be initiated.

\textit{Edit time delay seconds as required.}

4. After a boiler is signaled to start, the "ON" status shall be verified within specified time delay (seconds), or an alarm signal initiates.

5. As load diminisher the boilers shall be staged “off” in reverse order based on measured flow at either the crossover or the return leg from the system load.

6. Boiler safeties circuit shall generate an alarm signal if any safety switch trips.

7. Boilers - manufacturer supplied control will modulate the burner valve to maintain boiler hot water temperature.

8. DDC shall reset the boiler temperature in response to any hot water control valve signal from the AHU valve with the most demand. When any hot water control valve reaches maximum open position, the boiler hot water temperature setpoint will be reset higher. (Maximum temperature = 180°F, minimum temperature = 120°F).

9. Programs

a. DDC - PID setpoint control

b. Temperature reset

c. Control point switching

10. Control Points

\begin{itemize}
  \item a. Hot water system pump status AI AO BI BO X
  \item b. Boiler Status X
  \item c. Boiler Safeties Circuit X
  \item d. Boiler Temp. Reset X
  \item e. System HW crossover flow X
  \item f. System HW return line flow X
\end{itemize}

AI. Steam Boiler (SB)

\textit{Because frequent boiler shutdown can cause condensation in the fire box, it is desirable to have boiler operate for a substantial period through a time-delay control of several days.}

1. DDC controller shall start boiler in response to any heating demand as determined by steam coil control valves.

\textit{Or}

1. DDC controller shall start boiler in response to outside air temperature at and below setpoint (60°F).
Or
1. DDC schedule shall start boiler in autumn and shutdown in late spring.
2. The boiler's manufacturer supplied controls shall modulate burner valve to maintain header steam pressure setpoint.
3. Boiler pressure setpoint can be reset by operator.
4. Programs
   a. DDC - PID setpoint control
   b. Control Point Reset
5. Control Points

<table>
<thead>
<tr>
<th>Boiler start based on load</th>
<th>AI</th>
<th>AO</th>
<th>BI</th>
<th>BO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Steam coil control valves</td>
<td>X</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Boiler start based on outside temp.</th>
<th>AI</th>
<th>AO</th>
<th>BI</th>
<th>BO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Outside air temp.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Boiler start</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Boiler temp. reset</td>
<td>X</td>
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END OF SECTION