

SEQUENCE OF OPERATION

DEFINITIONS:

- PRIMARY LOOP: THE PRIMARY LOOP ON THE CHILLED WATER SYSTEM IS DEFINED AS THE CHILLER LOOP.
- SECONDARY LOOP: THE SECONDARY LOOP ON THE CHILLED WATER SYSTEM IS DEFINED AS THE BUILDING LOOP WHICH INCLUDES THE PLATE HEAT EXCHANGER 9-HX-1.

MODES OF OPERATION: THE PLANT SHALL BE CAPABLE OF OPERATING IN THE MANUAL OR AUTOMATIC MODE OF OPERATION.

MANUAL MODE: IN THE MANUAL MODE, ALL PUMPS, TOWERS, AND CHILLERS SHALL BE STARTED AND STOPPED MANUALLY. ALL MODULATED CONTROL FUNCTIONS SUCH AS TOWER FAN SPEED, PUMP SPEED, AND CHILLER CAPACITY CONTROL SHALL BE PERFORMED AUTOMATICALLY UNLESS OVERRIDDEN AT THE VFD OR UNIT CONTROL PANEL. CONTROL VALVES ASSOCIATED WITH CHILLERS, COOLING TOWERS, AND PLATE HEAT EXCHANGER SHALL REMAIN IN THEIR CURRENT POSITION UNLESS MANUALLY OVERRIDDEN.

AUTOMATIC MODE: IN THE AUTOMATIC MODE, ALL PUMPS, TOWERS, AND CHILLERS SHALL BE STARTED BY THE BAS. IN ADDITION THE BAS SHALL BE RESPONSIBLE FOR THE STAGING SEQUENCE OF PUMPS, TOWERS, PLATE HEAT EXCHANGERS AND CHILLERS. FIRST STAGE COOLING SHALL BE INITIATED IF ALL THE FOLLOWING CONDITIONS ARE SATISFIED:

- A SECONDARY CHILLED WATER PUMP IS ENABLED.
- A COOLING TOWER AND THE PLATE HEAT EXCHANGER OR A CHILLER ARE ENABLED.
- THE CONDENSER WATER SYSTEM IS FULL OF WATER.

AUTOMATIC MODE START-UP SEQUENCE: IF ALL OF THE ABOVE CONDITIONS ARE SATISFIED, PUMPS, TOWERS AND CHILLERS SHALL BE STARTED IN THE FOLLOWING SEQUENCE:

- START LEAD SECONDARY CHILLED WATER PUMP.
- ENABLE 1ST STAGE COOLING.

SECONDARY CHILLED WATER PUMP START/STOP CONTROL (9-P-7, 8 & 9): THE PUMPS SHALL HAVE A HAND-OFF-AUTO SWITCH IN THE VARIABLE FREQUENCY DRIVE. WHEN IN THE "HAND" POSITION THE PUMP SHALL OPERATE. WHEN IN THE "OFF" POSITION THE PUMP SHALL NOT OPERATE. WHEN IN THE "AUTO" POSITION, THE PUMP SHALL BE CONTROLLED BY THE BAS. HARDWIRED INTERLOCKS SHALL SHUTDOWN PUMP IF THE MOTOR OVERLOAD CONTACTS OPEN. PROGRAM BAS TO START A PUMP WHEN COOLING IS ENABLED AND TO STAGE PUMPS ON/OFF AS REQUIRED BASED ON FLOW. PROGRAM BAS TO ALTERNATE PUMPS TO EQUALIZE RUN TIME ON A WEEKLY BASIS BY STAGING ON THE NEW PUMP AND PROVING ITS STATUS PRIOR TO STAGING OFF THE OPERATING PUMP. THE PUMPS SHALL BE STAGED BASED ON THE PUMP WITH THE LEAST RUNTIME. IF THE SYSTEM AVERAGE FLOW IS ABOVE THE MAXIMUM FLOW SETPOINT FOR THE NUMBER OF PUMPS RUNNING (FOR 10 MINUTES, ADJUSTABLE), THE NEXT PUMP IN THE SEQUENCE SHALL START. IF THE SYSTEM AVERAGE FLOW IS BELOW THE MINIMUM FLOW SETPOINT FOR THE NUMBER OF PUMPS RUNNING, THE OPERATING PUMP WITH THE GREATEST RUN TIME SHALL STOP. A MINIMUM OF ONE (1) PUMP SHALL OPERATE AT A TIME AND PUMP ON/OFF STAGING SHALL BE BASED ON THE FOLLOWING SYSTEM FLOWS WHICH SHALL BE ADJUSTABLE:

CAMPUS FLOW (GPM)	PUMPS ON	PUMP ON PUMP OFF/PEAK FLOW (GPM)
2	800	600
3	1,400	1,100
		1,320
		1,980

SECONDARY CHILLED WATER PUMP STATUS (9-P-7, 8 & 9): A FAILURE OF THE PUMP AS DETERMINED BY AN ANALOG CURRENT SIGNAL OR FAULT ALARM FROM THE VFD SHALL, THROUGH THE DDC CONTROLLER, ISSUE A STOP COMMAND AND SIGNAL THE BAS OF A PUMP FAILURE. THE BAS SHALL IN TURN START A STANDBY SECONDARY CHILLED WATER PUMP IF AVAILABLE.

SECONDARY CHILLED WATER PUMP SPEED CONTROL (9-P-7, 8 & 9): ELECTRONIC ANALOG DIFFERENTIAL PRESSURE TRANSMITTERS LOCATED AT THE FAR END OF THE HOSPITAL CHILLED WATER LOOPS SHALL PROVIDE DIFFERENTIAL PRESSURE SIGNALS TO THE BAS. THE BAS SHALL IN TURN MODULATE THE SPEED OF THE VARIABLE FREQUENCY DRIVES TO MAINTAIN THE DIFFERENTIAL PRESSURE SETPOINT OF 6PSI (ADJUSTABLE) ON THE LOOP BASED ON THE LOWEST DIFFERENTIAL PRESSURE SENSED. THE BAS SHALL CONTROL ALL SECONDARY CHILLED WATER PUMPS AT A COMMON SPEED AND SHALL STAGE ON AN ADDITIONAL PUMP AND SEND AN ALARM SIGNAL IF THE PUMP SPEED REACHES 100% FOR MORE THAN 5 MINUTES.

PLATE HEAT EXCHANGER AND CHILLER STAGING SEQUENCE: PROOF OF OPERATION SHALL BE VERIFIED AT EACH STAGE OF START-UP AND SEQUENCING TO PREVENT REMOVING CAPACITY BEFORE PROVING OPERATION OF ENABLED EQUIPMENT. PROGRAM BAS TO ALTERNATE CHILLERS (9-CCU-1 & 9-SCU-1) TO EQUALIZE RUN TIME ON A WEEKLY BASIS BY STAGING ON THE NEW CHILLER AND PROVING ITS STATUS PRIOR TO STAGING OFF THE OPERATING CHILLER. THE PUMP SHALL BE CONTROLLED BY THE BAS. HARDWIRED INTERLOCKS SHALL SHUTDOWN PUMP IF THE MOTOR OVERLOAD CONTACTS OPEN. PROGRAM THE BAS TO OPERATE THE PRIMARY CHILLED WATER PUMPS CONTINUOUSLY WHEN ITS RESPECTIVE CHILLER OR PLATE HEAT EXCHANGER IS ENABLED. PROGRAM THE BAS TO OPERATE THE PRIMARY CHILLED WATER PUMP FOR 90 SECONDS AFTER ITS RESPECTIVE CHILLER IS DISABLED.

- STAGE 1 COOLING: PLATE HEAT EXCHANGER (9-HX-1), CONDENSER WATER PUMP (9-P-4 OR 5), AND COOLING TOWERS (9-CT-1 & 2) PLUS ONE (1) PRIMARY CHILLED WATER PUMP AND ASSOCIATED CHILLER.
- STAGE 2 COOLING: PLATE HEAT EXCHANGER (9-HX-1), CONDENSER WATER PUMP (9-P-4 OR 5), AND COOLING TOWERS (9-CT-1 & 2) PLUS ONE (1) PRIMARY CHILLED WATER PUMPS AND ASSOCIATED CHILLERS.
- STAGE 3 COOLING: PLATE HEAT EXCHANGER (9-HX-1), CONDENSER WATER PUMP (9-P-4 OR 5), AND COOLING TOWERS (9-CT-1 & 2) PLUS TWO (2) PRIMARY CHILLED WATER PUMPS AND ASSOCIATED CHILLERS.

CAPACITY STAGING CONTROL: A MINIMUM OF ONE STAGE OF CAPACITY SHALL BE ENABLED AT ALL TIMES. ADDITIONAL STAGES OF CAPACITY SHALL BE STAGED ON WHEN THE OPERATING EQUIPMENT CAN NOT MEET THE CHILLED WATER SUPPLY SETPOINT TEMPERATURE (TE-3) OF 45°F FOR MORE THAN 20 MINUTES OR THE CHILLED WATER SUPPLY TEMPERATURE (TE-3) RISES MORE THAN 2°F (ADJUSTABLE) ABOVE THE CHILLED WATER SUPPLY SETPOINT TEMPERATURE. STAGING UP SHALL BE LIMITED TO ONE STAGE EVERY 20 MINUTES. STAGING DOWN SHALL OCCUR AS FOLLOWS:

- STAGES 3 SHALL BE STAGED OFF WHEN THE CHILLER PLANT CAPACITY FALLS BELOW 225TONS FOR 20 MINUTES.
- STAGE 2 SHALL BE STAGED OFF WHEN THE CHILLED WATER SUPPLY SETPOINT TEMPERATURE AS SENSED BY (TE-2) HAS BEEN SATISFIED FOR 20 MINUTES.

PLATE HEAT EXCHANGER CAPACITY MONITORING: ELECTRONIC ANALOG TEMPERATURE SENSORS (TE-1 & TE-2) LOCATED ON THE CHILLED WATER RETURN SHALL SEND ANALOG SIGNALS TO THE BAS THAT ARE LINEAR WITH RESPECT TO THE TEMPERATURES SENSED. MAGNETIC OR ULTRASONIC FLOW METER LOCATED ON THE CAMPUS CHILLED WATER SUPPLY SHALL SEND AN ANALOG SIGNAL TO THE BAS THAT IS LINEAR WITH RESPECT TO THE FLOW SENSED. THE BAS SHALL IN TURN CALCULATE THE PLATE HEAT EXCHANGER CAPACITY AND RECORD THIS DATA IN TREND LOGS FOR HISTORICAL PURPOSES AND TO CALCULATE THE PLATE HEAT EXCHANGER EFFICIENCY.

PLATE HEAT EXCHANGER (9-HX-1) EFFICIENCY: THE PLATE HEAT EXCHANGER EFFICIENCY IN KW/TON SHALL BE CALCULATED BY DIVIDING ITS ASSOCIATED PUMP AND FANOWER FLOW BY THE PLATE HEAT EXCHANGER CAPACITY IN TONS. THE FOLLOWING EQUIPMENT AND METHOD SHALL BE INCLUDED IN CALCULATING THE PUMP AND FAN POWER HOWEVER ONLY 20% OF THE SECONDARY CHILLED WATER PUMP POWER SHALL BE USED IN THE CALCULATION.

EQUIPMENT	METHOD
SECONDARY CHILLED WATER PUMPS (9-P-7, 8 & 9)	CURRENT TRANSDUCER IN VFD - COMM. OVER BACNET
CONDENSER WATER PUMPS (9-P-4 & 5)	CURRENT TRANSDUCER IN VFD - COMM. OVER BACNET
COOLING TOWERS	CURRENT TRANSDUCER IN VFD - COMM. OVER BACNET

PLATE HEAT EXCHANGER (9-HX-1) ENABLE/DISABLE: THE BAS SHALL BE PROGRAMMED TO OPTIMIZE THE EFFICIENCY OF THE CHILLED WATER PLANT UNDER ALL LOAD CONDITIONS BASED ON THE AVAILABLE EQUIPMENT, OUTSIDE WEATHER CONDITIONS AND HISTORICAL OPERATING DATA. THE BAS SHALL DETERMINE IF THE PLATE HEAT EXCHANGER CAN BE OPERATED EFFICIENTLY BASED ON THE WET-BULB TEMPERATURE. WHEN THE PLATE HEAT EXCHANGER ENERGY CONSUMPTION EXCEEDS 0.4KW/TON (ADJUSTABLE), THE PLATE HEAT EXCHANGER SHALL BE DISABLED AND THE OUTSIDE WET BULB TEMPERATURE (OWBT) SHALL BE RECORDED AS THE DISABLED WET BULB TEMPERATURE (DWBT). WHEN THE OUTSIDE WET BULB TEMPERATURE (OWBT) FALLS 1°F (ADJUSTABLE) BELOW THE DISABLED WET BULB TEMPERATURE (DWBT), THE PLATE HEAT EXCHANGER SHALL BE ENABLED.

PLATE HEAT EXCHANGER (9-HX-1) CHILLED WATER BYPASS VALVE CONTROL (CV-1): THE PLATE HEAT EXCHANGER SHALL BE ENABLED BY THE BAS BY MODULATING THE CHILLED WATER BYPASS VALVE (CV-1), MODULATING THE CONDENSER SERIES/PARALLEL CONTROL VALVES (CV-2) AND MODULATING THE CHILLER BYPASS CONTROL VALVES (CV-3) AS FOLLOWS:

PLATE HEAT EXCHANGER (9-HX-1) CHILLED WATER BYPASS MIXING VALVE CONTROL (CV-1): ELECTRONIC ANALOG DIFFERENTIAL PRESSURE TRANSMITTERS PIPED ACROSS THE PLATE HEAT EXCHANGER CHILLED WATER PIPING SHALL PROVIDE A DIFFERENTIAL PRESSURE SIGNAL TO THE BAS. THE BAS SHALL IN TURN MODULATE THE CHILLED WATER BYPASS MIXING VALVE (CV-1) TO MAINTAIN A MAXIMUM DIFFERENTIAL PRESSURE SETPOINT OF 8PSI (ADJUSTABLE). IN THE EVENT THE DIFFERENTIAL PRESSURE RISES ABOVE SETPOINT, THE BAS SHALL MODULATE THE BYPASS MIXING VALVE (CV-1) OPEN. IN THE EVENT THAT THE PLATE HEAT EXCHANGER IS DISABLED, THE CHILLED WATER BYPASS MIXING VALVE (CV-1) SHALL BE MODULATED FULLY OPEN.

PLATE HEAT EXCHANGER (9-HX-1) CONDENSER WATER SERIES/PARALLEL VALVE CONTROL (CV-2): WHEN THE PLATE HEAT EXCHANGER IS ENABLED THE SERIES/PARALLEL BYPASS CONTROL VALVE (CV-2) SHALL BE MODULATED CLOSED AND THE PLATE HEAT EXCHANGER SHALL OPERATE IN SERIES WITH THE CHILLERS. WHEN THE PLATE HEAT EXCHANGER IS ENABLED AND A CHILLER IS ENABLED, CONTROL VALVE (CV-2) SHALL BE MODULATED IN SEQUENCE WITH (CV-3) TO MAINTAIN THE DIFFERENTIAL CONDENSER WATER PRESSURE SETPOINT OF 8PSI (ADJUSTABLE). IN THE EVENT THAT THE PLATE HEAT EXCHANGER IS DISABLED, THE SERIES/PARALLEL VALVE (CV-2) SHALL BE MODULATED FULLY OPEN.

PLATE HEAT EXCHANGER (9-HX-1) CONDENSER WATER CONTROL VALVE (CV-3): ELECTRONIC ANALOG DIFFERENTIAL PRESSURE TRANSMITTER PIPED ACROSS THE CONDENSER WATER SUPPLY AND RETURN MAINS SHALL SEND AN ANALOG SIGNAL TO THE BAS THAT IS LINEAR WITH RESPECT TO THE DIFFERENTIAL PRESSURE SENSED. WHEN THE PLATE HEAT EXCHANGER IS ENABLED AND THE CHILLERS ARE DISABLED, CONTROL VALVE (CV-3) SHALL BE MODULATED FULLY OPEN. WHEN THE PLATE HEAT EXCHANGER IS ENABLED AND A CHILLER IS ENABLED, CONTROL VALVE (CV-3) SHALL BE MODULATED TO MAINTAIN THE DIFFERENTIAL CONDENSER WATER PRESSURE SETPOINT OF 8PSI (ADJUSTABLE). WHEN THE PLATE HEAT EXCHANGER IS DISABLED, CONTROL VALVE (CV-3) SHALL BE MODULATED FULLY CLOSED.

EXISTING CHILLER CONTROL: THE CHILLED WATER PLANT HAS AN EXISTING WATER COOLED SCREW CHILLER (9-SCU-1), AN EXISTING TWO STAGE WATER COOLED ABSORPTION CHILLER (9-ACU-1) AND A PLATE HEAT EXCHANGER (9-HX-1). THE EXISTING CHILLERS ARE CONTROLLED BY THEIR PACKAGED MICROPROCESSOR BASED UNIT CONTROL PANELS. THE EXISTING UNIT CONTROL PANEL FOR THE ABSORPTION CHILLER (9-ACU-1) IS CONNECTED TO AND INTEGRATED TO THE BUILDING AUTOMATION SYSTEM. A NEW BACNET COMMUNICATIONS CARD SHALL BE PROVIDED AND INSTALLED IN THE EXISTING SCREW CHILLER (9-SCU-1) AND INTEGRATED TO THE BUILDING AUTOMATION SYSTEM. PROGRAM BAS AS FOLLOWS:

- TO ENABLE/DISABLE EACH CHILLER AND PLATE HEAT EXCHANGER IN ACCORDANCE WITH THE "CHILLER SEQUENCING SCHEDULE".
- TO SEND A CHILLED WATER SUPPLY RESET SIGNAL TO EACH OF THE CHILLER UNIT CONTROL PANELS. CHILLED WATER RESET SIGNAL SHALL BE BASED ON THE FURTHEST OPEN CHILLED WATER CONTROL VALVE.
- TO MONITOR ALL AVAILABLE ANALOG SIGNALS AND DIGITAL ALARMS FROM THE UNIT CONTROL PANELS.
- TO LOG AND TREND THE SCREW CHILLER ELECTRICAL LOAD VERSUS COOLING CAPACITY, CONDENSER WATER TEMPERATURES, AND CHILLED WATER TEMPERATURES.
- TO LOG AND TREND THE ABSORPTION CHILLER STEAM LOAD VERSUS COOLING CAPACITY, CONDENSER WATER TEMPERATURES, AND CHILLED WATER TEMPERATURES.

CHILLER (9-CCU-1) CONTROL: THE CHILLER IS CONTROLLED BY THEIR PACKAGED ELECTRONIC CONTROL SYSTEM. THE CHILLER IS ALSO CONTROLLED BY THE BUILDING AUTOMATION SYSTEM (BAS) THROUGH HARDWIRED POINTS AND FULLY INTEGRATED TO THE BUILDING AUTOMATION SYSTEM (BAS) THROUGH A BACNET INTERFACE TO ALLOW CONTROL, MONITORING AND ALARMING AT THE BAS. PROGRAM BAS AS FOLLOWS:

- TO ENABLE/DISABLE THE CHILLER IN ACCORDANCE WITH THE "PLATE HEAT EXCHANGER AND CHILLER STAGING SEQUENCE".
- TO RESET THE CHILLED WATER SUPPLY SETPOINT TEMPERATURE OF EACH CHILLER.
- TO MONITOR ALL HARDWIRED CONTROL POINTS AND CONTROL POINTS AVAILABLE THROUGH THE INTEGRATION INTERFACE INCLUDING TEMPERATURES, PRESSURES, SETPOINTS, STATUS INDICATION, AND DIGITAL ALARMS FROM THE CHILLER CONTROL PANEL.

CHILLER (9-CCU-1, 9-SCU-1 & 9-ACU-1) CAPACITY MONITORING: ELECTRONIC ANALOG TEMPERATURE SENSORS AND FLOW METER LOCATED ON THE CHILLER CHILLED WATER SUPPLY AND RETURN SHALL SEND ANALOG SIGNALS TO THE BAS THAT ARE LINEAR WITH RESPECT TO THE TEMPERATURES AND FLOW SENSED. THE BAS SHALL IN TURN CALCULATE THE CHILLER COOLING CAPACITY AND RECORD THIS DATA IN TREND LOGS FOR HISTORICAL PURPOSES.

CHILLER ENABLE/DISABLE: ELECTRONIC ANALOG TEMPERATURE SENSOR (TE-3) SHALL SEND ANALOG SIGNALS TO THE BAS THAT ARE LINEAR WITH RESPECT TO THE TEMPERATURE SENSED. IN THE EVENT THE CHILLED WATER SUPPLY TEMPERATURE AS SENSED BY (TE-3) RISES 2°F ABOVE SETPOINT, THE BAS SHALL ENABLE THE FIRST CHILLER (STAGE 2). IN THE EVENT THE CHILLED WATER SUPPLY TEMPERATURE AS SENSED BY (TE-3) REMAINS 2°F ABOVE SETPOINT FOR MORE THAN 20 MINUTES, THE BAS SHALL ENABLE THE SECOND CHILLER (STAGE 3). STAGING UP SHALL BE LIMITED TO ONE STAGE EVERY 20 MINUTES. WITH BOTH CHILLER STAGES OPERATING, IF THE CHILLER PLANT LOAD FALLS BELOW 225 TONS FOR 20 MINUTES, ONE CHILLER SHALL BE STAGED OFF (STAGE 2), WITH ONE CHILLER STAGE OPERATING, IF THE CHILLED WATER SUPPLY TEMPERATURE AS SENSED BY (TE-2) FALLS TO WITHIN 1°F OF SETPOINT, THE LAST CHILLER SHALL BE STAGED OFF (STAGE 1).

CHILLER (9-CCU-1, 9-SCU-1 & 9-ACU-1) CHILLED WATER SUPPLY RESET SCHEDULE: ELECTRONIC ANALOG TEMPERATURE SENSOR (TE-3) LOCATED ON THE SECONDARY CHILLED WATER SUPPLY TO THE LABORATORY SHALL SEND AN ANALOG SIGNAL TO THE BAS THAT IS LINEAR WITH RESPECT TO THE TEMPERATURE SENSED. THE BAS SHALL IN TURN RESET THE CHILLER CHILLED WATER SUPPLY SETPOINT TEMPERATURE FROM 45°F TO 40°F AS REQUIRED TO MAINTAIN THE SECONDARY CHILLED WATER SUPPLY SETPOINT TEMPERATURE OF 45°F AS SENSED BY (TE-3). THE CHILLER CHILLED WATER SUPPLY SETPOINT TEMPERATURE SHALL BE CONTROLLED BY A PID LOOP OR THE FOLLOWING EQUATION:

$$PCHWSPTS = TE2 - [SCHWFLOW \times (TE2 - SCHWSPTS)] / (PCHWFLOW)$$

WHERE:

TE2 = CHILLED WATER RETURN TEMPERATURE DOWNSTREAM OF PLATE HEAT EXCHANGER.

PCHWSPTS = PRIMARY CHILLED WATER SUPPLY SETPOINT TEMPERATURE

PCHWFLOW = PRIMARY CHILLED WATER FLOW.

SCHWSPTS = SECONDARY CHILLED WATER SUPPLY SETPOINT TEMPERATURE

SCHWFLOW = SECONDARY CHILLED WATER FLOW.

CHILLER CONDENSER WATER FLOW SWITCH: THE CHILLERS HAVE A FLOW SWITCH ON THE CHILLED AND CONDENSER WATER PIPING INTERLOCKED TO PREVENT OPERATION UNTIL FLOW IS PROVEN.

PROVIDE A BAS RELAY IN THE UNIT CONTROL PANEL SERVING CHILLER (9-CCU-1). WIRE BAS RELAY CONTACTS IN PARALLEL TO THE CHILLERS EXISTING CONDENSER WATER FLOW SWITCH. IN THE EVENT THAT THE CONDENSER WATER TEMPERATURE IS BELOW 50°F (ADJUSTABLE), THE BAS SHALL CLOSE THE RELAY CONTACTS TO SIMULATE FLOW AND ALLOW THE CHILLER TO OPERATE UNDER HEAD PRESSURE CONTROL. IN THE EVENT THAT THE CONDENSER WATER TEMPERATURE IS ABOVE 60°F (ADJUSTABLE) THE BAS RELAY CONTACTS SHALL BE OPEN TO ALLOW THE FLOW SWITCH TO SHUT DOWN CHILLER IN THE EVENT OF LOSS OF FLOW.

CHILLER CHILLED WATER VALVE CONTROL (9-CCU-1, 9-SCU-1 & 9-ACU-1): NORMALLY OPEN 2-POSITION CONTROL VALVE ON THE CHILLED WATER RETURN TO EACH CHILLER SHALL BE INTERLOCK THROUGH SOFTWARE TO OPEN WHEN ITS RESPECTIVE CHILLER IS ENABLED.

HEAD PRESSURE CONTROL (9-CCU-1 & 9-SCU-1): THE CHILLERS HAVE AN ELECTRONIC ANALOG DIFFERENTIAL REFRIGERANT PRESSURE SENSOR PIPED ACROSS THE CONDENSER AND EVAPORATOR ON EACH CHILLER. DIFFERENTIAL REFRIGERANT PRESSURE SENSOR SHALL SEND AN ANALOG SIGNAL TO THE UNIT CONTROL PANEL WHICH SHALL IN TURN MODULATE THE NORMALLY OPEN HEAD PRESSURE CONTROL VALVES ON THE CONDENSER WATER SUPPLY IN SEQUENCE TO MAINTAIN THE HEAD PRESSURE SETPOINT AS RECOMMENDED BY THE CHILLER MANUFACTURER. AS THE HEAD PRESSURE INCREASES ABOVE SETPOINT, THE UNIT CONTROL PANEL SHALL MODULATE THE HEAD PRESSURE CONTROL VALVES OPEN. AS THE HEAD PRESSURE DECREASES BELOW SETPOINT, THE UNIT CONTROL PANEL SHALL MODULATE THE HEAD PRESSURE CONTROL VALVES CLOSED. HEAD PRESSURE CONTROL VALVES SHALL BE CLOSED WHEN THE RESPECTIVE CHILLER IS DISABLED.

PRIMARY CHILLED WATER PUMP ASSIGNMENT (9-P-1, 9-P-2, & 9-P-3): THE PRIMARY CHILLED WATER PUMPS SHALL BE ASSIGNED TO A SPECIFIC CHILLER WITH THE ABILITY TO RE-ASSIGN ONE OF THE PUMPS TO A DIFFERENT CHILLER IN THE EVENT OF A PUMP FAILURE. PROGRAM THE PUMP SPEED CONTROL PROGRAMMING TO FOLLOW THE RESPECTIVE CHILLER FLOW CONTROL REQUIREMENTS. THE FOLLOWING SHALL BE THE BASE ASSIGNMENT OF THE PRIMARY CHILLED WATER PUMPS:

PRIMARY CHILLED WATER PUMP/CHILLER	9-P-1	9-CCU-1
	9-P-2	9-ACU-1
	9-P-3	9-SCU-1

PRIMARY CHILLED WATER PUMP START/STOP CONTROL (9-P-1, 9-P-2, & 9-P-3): THE PUMPS SHALL HAVE A HAND-OFF-AUTO SWITCH IN THE VARIABLE FREQUENCY DRIVE. WHEN IN THE "HAND" POSITION THE PUMP SHALL OPERATE. WHEN IN THE "OFF" POSITION THE PUMP SHALL NOT OPERATE. WHEN IN THE "AUTO" POSITION, THE PUMP SHALL BE CONTROLLED BY THE BAS. HARDWIRED INTERLOCKS SHALL SHUTDOWN PUMP IF THE MOTOR OVERLOAD CONTACTS OPEN. PROGRAM THE BAS TO OPERATE THE PRIMARY CHILLED WATER PUMPS CONTINUOUSLY WHEN ITS RESPECTIVE CHILLER OR PLATE HEAT EXCHANGER IS ENABLED. PROGRAM THE BAS TO OPERATE THE PRIMARY CHILLED WATER PUMP FOR 90 SECONDS AFTER ITS RESPECTIVE CHILLER IS DISABLED.

PRIMARY CHILLED WATER PUMP STATUS (9-P-1, 2 & 3): A FAILURE OF THE PUMP AS DETERMINED BY AN ANALOG CURRENT SIGNAL OR FAULT ALARM FROM THE VFD SHALL, THROUGH THE DDC CONTROLLER, ISSUE A STOP COMMAND AND SIGNAL THE BAS OF A PUMP FAILURE.

PRIMARY CHILLED WATER PUMP SPEED CONTROL (9-P-1, 2 & 3): MAGNETIC FLOW METER/TRANSMITTERS LOCATED ON THE CHILLED WATER RETURN TO EACH OF THE CHILLERS SHALL PROVIDE FLOW SIGNALS TO THE BAS THAT ARE LINEAR WITH RESPECT TO THE FLOWS SENSED. FOR CHILLERS (9-CCU-1 & 9-SCU-1) THE BAS SHALL IN TURN MODULATE THE SPEED OF THE VARIABLE FREQUENCY DRIVES TO MAINTAIN A FLOW RATE PROPORTIONAL TO THE CHILLER OPERATING CAPACITY WITH A MINIMUM FLOW RATE BASED ON THE CHILLER MINIMUM FLOW RATE. THE CHILLER MINIMUM FLOW RATES ARE 225GPM AND 357GPM FOR CHILLERS (9-CCU-1 & 9-SCU-1) RESPECTIVELY. THE CHILLED WATER FLOW RATE FOR THE ABSORPTION CHILLER (9-ACU-1) SHALL BE CONSTANT AND SHALL BE SET FOR 480GPM.

CAMPUS COOLING LOAD MONITORING: ELECTRONIC ANALOG INPUT SIGNALS SHALL BE RECEIVED BY THE BAS FROM THE MAGNETIC OR ULTRASONIC FLOW METER AND TEMPERATURE SENSORS LOCATED ON THE SECONDARY CHILLED WATER SUPPLY AND RETURN FROM THE CAMPUS. THE BUILDING AUTOMATION SYSTEM SHALL IN TURN CALCULATE THE CAMPUS COOLING LOAD IN TONS AND RECORD THIS DATA IN TREND LOGS FOR HISTORICAL PURPOSES.

ENERGY METERING: ENERGY CONSUMPTION FOR ALL CHILLER PLANT EQUIPMENT SHALL BE PROVIDED TO THE BAS BY THE FOLLOWING METHOD:

EQUIPMENT	METHOD
PRIMARY CHILLED WATER PUMPS (9-P-1, 2 & 3)	CURRENT TRANSDUCER IN VFD - COMM. OVER BACNET
SECONDARY CHILLED WATER PUMPS (9-P-7, 8 & 9)	CURRENT TRANSDUCER IN VFD - COMM. OVER BACNET
CONDENSER WATER PUMPS (9-P-4 & 5)	CURRENT TRANSDUCER IN VFD - COMM. OVER BACNET
COOLING TOWERS	CURRENT TRANSDUCER IN VFD - COMM. OVER BACNET
CHILLER (9-CCU-1)	ENERGY METER VIA BACNET INTEGRATION
CHILLER (9-SCU-1)	ENERGY METER VIA BACNET INTEGRATION
CENTRIFUGAL SEPARATOR PUMP	MANUALLY MEASURED AND INPUT TO THE BAS (77A)

CONDENSER WATER PUMP START/STOP CONTROL (9-P-4 & 9-P-5): THE PUMPS SHALL HAVE A HAND-OFF-AUTO SWITCH IN THE VARIABLE FREQUENCY DRIVE. WHEN IN THE "HAND" POSITION THE PUMP SHALL OPERATE. WHEN IN THE "OFF" POSITION THE PUMP SHALL NOT OPERATE. WHEN IN THE "AUTO" POSITION, THE PUMP SHALL BE CONTROLLED BY THE BAS. HARDWIRED INTERLOCKS SHALL SHUTDOWN THE PUMP IF THE MOTOR OVERLOAD CONTACTS OPEN. EACH CHILLER SHALL SEND A CONDENSER WATER PUMP START/STOP SIGNAL TO THE BAS UPON A CALL FOR COOLING. PROGRAM THE BAS TO OPERATE ONE CONDENSER WATER PUMP WHEN ONE CHILLER OR PLATE HEAT EXCHANGER IS ENABLED AND TWO PUMPS WHEN TWO CHILLERS ARE ENABLED.

CONDENSER WATER PUMP SPEED CONTROL (9-P-4 & 9-P-5): MAGNETIC FLOW METER/TRANSMITTERS LOCATED ON THE MAIN CONDENSER WATER SUPPLY AND THE CONDENSER WATER RETURN ON CHILLERS (9-CCU-1 & 9-SCU-1) SHALL PROVIDE A FLOW SIGNALS TO THE BAS THAT ARE LINEAR WITH RESPECT TO THE FLOW SENSED. ELECTRONIC ANALOG DIFFERENTIAL PRESSURE TRANSMITTER PIPED ACROSS THE CONDENSER WATER SUPPLY AND RETURN SHALL SEND A DIFFERENTIAL PRESSURE SIGNAL TO THE BAS THAT IS LINEAR WITH RESPECT TO THE DIFFERENTIAL PRESSURE SENSED. THE BAS SHALL IN TURN MODULATE A 4-20mA SIGNAL TO THE VARIABLE FREQUENCY DRIVE TO MAINTAIN THE FOLLOWING CONDITION:

- WHEN THE PLATE HEAT EXCHANGER IS ENABLED (STAGE 1 OR 2), THE BAS SHALL MODULATE THE SPEED OF THE CONDENSER WATER PUMPS TO MAINTAIN THE CONDENSER WATER FLOW BASED ON THE FOLLOWING EQUATION:

$$COND. WATER FLOW = 400 + 370 * [SUM OF TOWER SPEEDS (%) / 100]$$

- WHEN ONE OR MORE CHILLERS ARE ENABLED (STAGE 2 OR 3), THE BAS SHALL SUM THE CONDENSER WATER DESIGN FLOWS OF THE OPERATING CHILLERS AND MODULATE THE SPEED OF THE CONDENSER WATER PUMPS TO MAINTAIN THE SUM OF THE ENABLED CHILLER CONDENSER WATER DESIGN FLOW RATES OR THE PLATE HEAT EXCHANGER FLOW RATE AS CALCULATED IN ITEM 1 ABOVE WHICHEVER IS HIGHER. THE DESIGN FLOW RATE OF CHILLERS (9-CCU-1 AND 9-SCU-1) ARE 750GPM AND 704GPM RESPECTIVELY.

CONDENSER WATER PUMP STATUS (9-P-4 & 9-P-5): A FAILURE OF THE PUMP AS DETERMINED BY A DIGITAL CURRENT SWITCH OR VFD FAULT SIGNAL SHALL, THROUGH THE DDC CONTROLLER, ISSUE A STOP COMMAND AND SIGNAL THE BAS OF A PUMP FAILURE. A FAILURE OF THE PUMP AS DETERMINED BY THE CURRENT SWITCH OR VFD FAULT ALARM SIGNAL SHALL, THROUGH THE DDC CONTROLLER, ISSUE A STOP COMMAND AND SIGNAL THE BAS OF A PUMP FAILURE. THE BAS SHALL IN TURN START A STANDBY PUMP.

CONDENSER WATER PUMP (9-P-4 & 5) CLOGGED STRAINER ALARM: AN ELECTRONIC ANALOG DIFFERENTIAL PRESSURE TRANSMITTER PIPED ACROSS THE BASKET STRAINER SHALL SEND AN ANALOG SIGNAL TO THE BAS THAT IS LINEAR WITH RESPECT TO THE DIFFERENTIAL PRESSURE SENSED. THE BAS SHALL IN TURN SEND AN ALARM SIGNAL TO THE BAS IF THE DIFFERENTIAL PRESSURE EXCEEDS 4 PSI (ADJUSTABLE) FOR MORE THAN 5 MINUTES.

COOLING TOWER CONDENSER WATER RETURN VALVE CONTROL (CV-4 & 5): THE COOLING TOWERS (9-CT-1 & 2) SHALL BE ENABLED BY OPENING THEIR RESPECTIVE CONDENSER WATER RETURN VALVES (CV-4 & 5) AND DISABLED BY CLOSING THEIR RESPECTIVE CONDENSER WATER RETURN VALVES (CV-4 & 5).

COOLING TOWER FAN START/STOP CONTROL (9-CT-1, & 9-CT-2): THE COOLING TOWER FANS SHALL HAVE A HAND-OFF-AUTO SWITCH IN THE VARIABLE FREQUENCY DRIVE. WHEN IN THE "HAND" POSITION THE FAN SHALL OPERATE. WHEN IN THE "OFF" POSITION THE FAN SHALL NOT OPERATE. WHEN IN THE "AUTO" POSITION, THE FAN SHALL BE CONTROLLED BY THE BAS. HARDWIRED INTERLOCKS SHALL SHUTDOWN FAN IF THE MOTOR OVERLOAD OR TOWER VIBRATION SWITCH CONTACTS OPEN. PROGRAM THE BAS TO STAGE THE COOLING TOWER FANS ON IN SEQUENCE WITH THE CONDENSER WATER BYPASS VALVE CLOSING. WHEN THE OPERATING COOLING TOWER FAN(S) FAN SPEED INCREASES ABOVE 75 PERCENT (ADJUSTABLE), THE BAS SHALL ENABLE ANOTHER COOLING TOWER AND START ITS FAN. WHEN THE OPERATING COOLING TOWER FAN(S) SPEED FALLS BELOW 25 PERCENT (ADJUSTABLE) THE BAS SHALL STOP A COOLING TOWER FAN. PROGRAM BAS TO ALTERNATE COOLING TOWER FAN LEAD/LAG SEQUENCE ON A FIRST-ON-FIRST-OFF AND MONTHLY BASIS.

COOLING TOWER FAN STATUS (9-CT-1 & 9-CT-2): A FAILURE OF THE FAN AS DETERMINED BY A DIGITAL CURRENT SWITCH OR VFD FAULT ALARM SIGNAL SHALL, THROUGH THE DDC CONTROLLER, ISSUE A STOP COMMAND AND SIGNAL THE BAS OF A COOLING TOWER FAN FAILURE. PROGRAM BAS TO START STANDBY COOLING TOWER IF AVAILABLE.

COOLING TOWER FAN SPEED CONTROL (9-CT-1 & 9-CT-2): ELECTRONIC ANALOG TEMPERATURE SENSOR LOCATED IN THE CONDENSER WATER SUMP SHALL PROVIDE AN ELECTRONIC ANALOG SIGNAL TO THE BAS WHICH IS LINEAR WITH RESPECT TO THE TEMPERATURE SENSED. THE DDC CONTROLLER SHALL IN TURN MODULATE AN ELECTRONIC ANALOG SIGNAL TO THE COOLING TOWER VFD'S AND COOLING TOWER BYPASS VALVE TO MAINTAIN THE CONDENSER WATER SUMP (SUPPLY) SETPOINT TEMPERATURE. THE MINIMUM COOLING TOWER FAN SPEED SHALL BE SET IN THE VFD AND BAS TO 12HZ (20%) TO PROVIDE ADDITIONAL TURNDOWN CAPACITY.

CONDENSER WATER SUMP (SUPPLY) SETPOINT TEMPERATURE: WHEN THE PLATE HEAT EXCHANGER (9-HX-1) IS DISABLED, AND A CHILLER IS ENABLED, THE CONDENSER WATER SUPPLY SETPOINT TEMPERATURE SHALL BE RESET FROM 75°F WHEN THE WETBULB TEMPERATURE IS 63°F TO 65°F WHEN THE WET BULB TEMPERATURE IS 52°F WITH A STRAIGHT LINE RELATIONSHIP BETWEEN. IN THIS MODE OF OPERATION, THE CONDENSER WATER SUPPLY TEMPERATURE SHALL BE A MINIMUM OF 12°F ABOVE THE CHILLED WATER SUPPLY TEMPERATURE. WHEN THE PLATE HEAT EXCHANGER (9-HX-1) IS ENABLED, THE CONDENSER WATER SUPPLY SETPOINT TEMPERATURE SHALL BE RESET TO 42°F TO MAINTAIN A CHILLED WATER SUPPLY SETPOINT AT 45°F.

COOLING TOWER BYPASS VALVE CONTROL (CV-6): AN ELECTRONIC ANALOG TEMPERATURE SENSOR IN THE CONDENSER WATER SUMP SHALL SEND AN ANALOG SIGNAL TO THE BAS WHICH IS LINEAR WITH RESPECT TO THE SUMP TEMPERATURE. THE BAS SHALL IN TURN MODULATE ELECTRONIC ANALOG SIGNALS TO THE COOLING TOWER BYPASS VALVE (CV-6) ON THE CONDENSER WATER IN BETWEEN THE CHILLERS AND THE COOLING TOWER. THE CONTROL VALVES (CV-4 AND/OR CV-5) TO THE COOLING TOWERS. PROGRAM THE BAS TO MODULATE THE COOLING TOWER BYPASS VALVE (CV-6) OPEN AND THE COOLING TOWER CONTROL VALVES (CV-4 AND/OR 5) CLOSED WHEN THE CONDENSER WATER SUMP TEMPERATURE IS BELOW SETPOINT TEMPERATURE AND MODULATE THE COOLING TOWER BYPASS VALVE (CV-6) CLOSED AND THE COOLING TOWER CONTROL VALVES (CV-4 AND/OR 5) OPEN WHEN THE CONDENSER WATER SUMP TEMPERATURE IS ABOVE SETPOINT TEMPERATURE.

CENTRIFUGAL SEPARATOR PUMP (9-P-10) START/STOP CONTROL: THE PUMP SHALL HAVE A HAND-OFF-AUTO SWITCH IN THE SEPARATOR CONTROL PANEL FOR THE PUMP MOTOR STARTER. WHEN IN THE "HAND" POSITION, THE PUMP SHALL OPERATE. WHEN IN THE "OFF" POSITION THE PUMP SHALL NOT OPERATE. WHEN IN THE "AUTO" POSITION, THE PUMP SHALL BE CONTROLLED BY THE BAS. HARDWIRED INTERLOCKS SHALL SHUTDOWN PUMP IF THE MOTOR OVERLOAD CONTACTS OPEN. PROGRAM THE BAS TO OPERATE THE CENTRIFUGAL SEPARATOR PUMP CONTINUOUSLY WHEN THE SUMP IS WITHIN ITS NORMAL WATER LEVEL.

CENTRIFUGAL SEPARATOR PUMP (9-P-10) STATUS: A FAILURE OF THE PUMP AS DETERMINED BY A DIGITAL CURRENT SWITCH SHALL, THROUGH THE DDC CONTROLLER, ISSUE A STOP COMMAND AND SIGNAL THE BAS OF A PUMP FAILURE.

CENTRIFUGAL SEPARATOR BLOWDOWN VALVE CONTROL (CV-9): THE CONDUCTIVITY CONTROLLER SHALL SEND A DIGITAL SIGNAL TO THE BAS WHEN THE CONDENSER WATER CONDUCTIVITY RISES ABOVE SETPOINT. IF THE CENTRIFUGAL SEPARATOR PUMP (9-P-10) IS OPERATING, THE BAS SHALL IN TURN OPEN THE BLOWDOWN VALVE (CV-9) ON THE CENTRIFUGAL SEPARATOR TO BLOWDOWN THE CONDENSER WATER SYSTEM FOR A PREDETERMINED TIME PERIOD AS DETERMINED BY THE CHEMICAL TREATMENT SUPPLIER. PROGRAM THE BAS TO OPEN THE CENTRIFUGAL SEPARATOR BLOWDOWN VALVE (CV-9) FOR 60SECONDS (ADJUSTABLE) EVERY 24 HOURS (ADJUSTABLE) WHEN THE CENTRIFUGAL SEPARATOR PUMP (9-P-10) IS OPERATING.

STRAINER BLOWDOWN VALVE CONTROL (CV-8): PROGRAM THE BAS TO OPEN THE STRAINER BLOWDOWN VALVE (CV-8) FOR 60SECONDS (ADJUSTABLE) EVERY 24 HOURS (ADJUSTABLE) WHEN A CONDENSER WATER PUMP (9-P-4 OR 5) ARE OPERATING. IN THE EVENT THAT THE CENTRIFUGAL SEPARATOR PUMP IS NOT OPERATING AND THE BAS RECEIVES A BLOWDOWN SIGNAL FROM THE CONDUCTIVITY CONTROLLER, THE BAS SHALL OPEN THE STRAINER BLOWDOWN VALVE (CV-8) FOR A PREDETERMINED TIME PERIOD AS DETERMINED BY THE CHEMICAL TREATMENT SUPPLIER.

MAKE-UP WATER VALVE CONTROL (CV-10): AN ELECTRONIC ANALOG LEVEL SENSOR LOCATED IN THE INDOOR CONDENSER WATER SUMP SHALL PROVIDE AN ANALOG INPUT SIGNAL TO THE BAS. THE BAS SHALL IN TURN CONTROL THE OPEN/CLOSED STATUS OF THE NORMALLY CLOSED CONDENSER WATER MAKE-UP VALVE (CV-10) TO MAINTAIN THE INDOOR CONDENSER WATER SUMP WATER LEVEL. PROGRAM BAS AS FOLLOWS:

- TO SIGNAL A LOW LEVEL ALARM AND SHUT DOWN THE CONDENSER WATER PUMPS IF THE SUMP WATER LEVEL FALLS BELOW 36"
- TO OPEN THE MAKE-UP WATER VALVE (CV-10) IF THE SUMP WATER LEVEL FALLS BELOW 58" WITH ONE PUMP OPERATING OR BELOW 42" WITH TWO PUMPS OPERATING.
- TO CLOSE THE MAKE-UP WATER VALVE (CV-10) IF THE SUMP WATER LEVEL RISES ABOVE 60" WITH ONE PUMP OPERATING OR ABOVE 46" WITH TWO PUMPS OPERATING.
- TO SIGNAL A HIGH LEVEL ALARM IF THE SUMP WATER LEVEL RISES ABOVE 75".

CONDENSER WATER MAKE-UP MONITORING AND ALARM: WATER METER SHALL SEND A PULSE SIGNAL TO THE BAS TO INDICATE MAKE-UP WATER QUANTITY. THE BAS SHALL IN TURN LOG THE MAKE-UP WATER FOR HISTORICAL DATA AND SIGNAL AN ALARM CONDITION IF THE MAKE-UP WATER FLOW BECOMES CONTINUOUS OR EXCESSIVE AS DETERMINED BY HISTORICAL DATA.

CONDUCTIVITY MONITORING & ALARM: AN ELECTRONIC ANALOG CONDUCTIVITY SENSORS LOCATED IN THE CONDENSER WATER CHEMICAL TREATMENT PIPING SHALL SEND A CONDUCTIVITY SIGNAL TO THE BAS. THE BAS SHALL LOG THE CONDENSER WATER CONDUCTIVITY FOR HISTORICAL DATA AND SIGNAL AN ALARM IF THE CONDUCTIVITY EXCEEDS 1,000 MOHS.

EQUIPMENT OVERRIDES: EQUIPMENT SHALL BE MANUALLY CONTROLLED THROUGH THEIR RESPECTIVE HAND-OFF-AUTO SWITCHES AT THEIR RESPECTIVE MOTOR STARTERS OR VARIABLE FREQUENCY DRIVES.

RUNTIME: INITIATE A RUNTIME CALCULATION UPON A START COMMAND FOR EACH PUMP, CHILLER, AND COOLING TOWER. CALCULATE RUNTIME IN HOURS AND TOTALIZE THE HOURS FOR EACH DAY, WEEK, MONTH, AND YEAR. INTERRUPT THE RUNTIME CALCULATION UPON A STOP COMMAND.